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VOLUME 39 — OCTOBER, 1955 — NUMBER 4

CONTENTS

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THE ENERGY CONCEPT IN GENERAL EDUCATION

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Science instruction, for purposes of general education throughout the range from kindergarten through junior college, needs a unifying principle. Such science instruction needs this not only to correlate the teachings from grade to grade but, also, to provide a comprehensive picture of the environment. The need has always existed but it is becoming increasingly acute [3], [10], [11], [13], [14].

Three factors mark the situation as critical. They are: the nature and direction of scientific advance, implications of research in the teaching of the sciences and changing conceptions of the psychology of learning.

Let us consider the advance of science. To illustrate, we select a few steps from a vast succession that is available in the most active and significant area of development [1], [12], [16].

In 1895 Wilhelm Roentgen discovered X-rays. Roentgen found that highly exhausted glass tubes, through which electric discharges were passing, gave out invisible radiations. He found that these invisible radiations fogged photographic plates that were protected by several thicknesses of wrapping paper. This was the start of a trend in a development of science that presents our problem and opportunity today.

One year later Henri Becquerel detected radiation, with properties similar to those of Roentgen, from the double sulfate of potassium and uranium. Upon further investigation, he found that uranium and all of its compounds emitted these radiations. Like the uranium radiations, they were invisible and they affected the protected photographic plate.

Becquerel's discovery was followed by an observation that led the Curies to their search for radium. It had been noted that both the X-rays and the radiations from uranium produced electrical conductivity in air and other gases. M. and Mm. Curie began a systematic search for elements, compounds and natural substances that would produce this effect. They found several such substances in pitchblende and, as a result of their search, isolated radium. Then, Curie and Laborde detected a constant emission of heat from radium.

Soon thereafter, between 1901 and 1904, further correlations were established between matter and energy. Max Planck announced his Quantum Theory. This theory postulated that energy manifests itself in discreet amounts and that the structure of light is essentially atomic. Coinciding with Planck's correlation Elster, Geitel, and Wilson demonstrated the presence of a persistent conductivity in the cloud ionization chamber. They pointed out that such phenomena suggest a source of radiation from outside the earth. Elster and Geitel investigated further concerning the emission of corpuscles or electrons from substances at high temperatures and from metals under the influence of ultra-violet light.

Albert Einstein correlated the preceding investigations and opened new fields of discovery. In 1905, as part of his "Special Theory of Relativity," he formulated his equation representing the equivalence of mass and energy. This equation, besides stating an identity of mass and energy, indicated an astounding ratio of equivalence—

one pound of mass equals 10.66 billion kilowatt-hours of energy. We note that Einstein's constant is the speed of light and that his equation utilizes a manifestation of energy (light) with which even children are familiar.

Einstein's equation was followed by a description of the distribution of mass and energy in the atom. In 1911, Sir Ernest Rutherford pictured the atom as a complex body of open structure with electrons revolving around a central nucleus. This nucleus, besides comprising most of the weight of the atom, contained just sufficient positive charges to balance the negative charges of the revolving electrons. Rutherford compared the atom to the solar system, suggesting similarity of the energy that pervades both.

Let us keep in mind that our purpose is not to present a detailed discussion of any particular area of science but that it is to review significant trends in science that are essential to an appreciation of a need for curricular unification. Accordingly, we proceed with mention of a few more advances.

Rutherford had compared the nucleus of the atom to the sun. H. A. Bethe, in 1942, studied the sources of solar energy and established a cycle of energy transformation involving hydrogen, carbon, and helium. Thus, Bethe demonstrated correlations between energy emissions from the sun and those from atoms of terrestrial matter.

To bring this series of correlations to the present and to include implications from the biological and chemical sciences, let us note two further advances.

We note the recent research on radioactive carbon 14. We find that this form of carbon is produced by cosmic rays and that there is sufficient in organic matter to constitute an important source of radiation for the living body. Thus, life is linked with other discoveries that we have discussed; especially with those of Bethe, Elster, Geitel, and Wilson.

Second, consider the links in the chain of bio-energetics forged by studies of the process of photosynthesis. Chlorophyll phosphoresces, while it phosphoresces it becomes magnetic and when it is magnetic it absorbs light. By means of an interaction of light, phosphorescence and magnetism, a molecule of chlorophyll builds sugars and starches, even though the phosphorescence lasts but a tenth of a second.

The foregoing summarization suggests curriculum content that should be made available to learners in our schools throughout the grade range from one to fourteen. This content, at particular levels of maturation, may include relatively few facts; always, however, it can be made rich with meanings. Besides, the summarization indicates need of a unifying concept and it provides a concept of sufficient generality and inclusiveness to serve that purpose.

> "A few remarks are in order on the nature of the concepts that are likely to accomplish this purpose (integrating the data of experience). They must inevitably be very general. This is always the nature of common denominator terms. The more one integrates the more one moves toward abstract ideas" [13].

The principle of conservation of energy places our modern interpretations of man and universe in a context that integrates all sciences.

We examine, next, implications of research from two other sources—Science Education and Educational Psychology.

The most recently published digest and discussion of research in the teaching of the sciences is Part I of the Forty-Sixth Yearbook of the National Society for the Study of Education [3]. Here we find recommendations relating to curricula, methods of instruction, objectives and social implications. A major theme of the Yearbook is the necessity for directing instruction in science on all grade levels toward broad and comprehensive interpretations. "A fundamental purpose, then, in the education of children must be to give the kind of guidance which leads them to make adjustments to the world about them through interpretations that are consistent with the best statements of truth available" (p. 60).

The scientific advances that we have just reviewed are representative of those that are broadening the world about our students. It is to this world that our students need guidance and adjustment. Such guidance will come from a program of instruction that integrates and interprets this newly discovered truth.

But the Forty-Sixth Yearbook does more than recommend that we direct instruction toward interpretations. It presents a selection of carefully formulated interpretations and it selects one for special emphasis. "The functional understanding, for example, of such a principle as 'energy can be changed from one form to another' is basic to an understanding of physical science and of many human relationships. It has far reaching social and economic relationships. As the learner's understanding of such a principle grows, he will attain a more intelligent and sympathetic appreciation of many problems of the world in which he lives" (p. 31).

The concept embodied in the statement that "energy can be changed from one form to another"—the Law of Conservation of Energy—is a master concept of Science and Science Education.

Thus, from an analysis of recent advances in science and from statements of educational implications of those advances we establish a need for curricular unification in the teaching of the sciences. Further, from these two sources we find a unifying concept. What, now, are some contributions from educational psychologists?

Educational psychologists have tested and validated the Law of the Whole [6], [15]. During the past two decades, the subjects that have made great progress in our schools are those that have organized content and method in terms of this law. In accordance therewith, generalities are presented before details. In the teaching of the sciences this means that factual elements are preceded by a basic concept and that learning is a differentiation of that concept. As we have seen, the concept involved in recent scientific advance and the concept accepted by students of research in the teaching of the sciences is the concept of energy conservation and transformation.

Further, educational psychologists say that not only should the order of teaching proceed from wholes to parts but that the parts are explainable only in terms of the whole [6], [15]. Examine a few questions: What is light? What is heat? How are rocks formed? What produces phenomena of weather? How do green plants make food? What is the significance of the spatial and temporal relationships of earth, sun, and moon in the maintenance of life on the earth? How is animal instinct an adaptation to energy? How is intelligence an adaptation to energy? Note the inclusiveness of each of these questions and the possibilities of interpretation in terms of the concept of energy. When we consider the details comprehended by these questions we realize how parts derive meaning from larger wholes.

Finally, consider one further implication from the researches of educational psychologists. These researches indicate that our perceptions give us the conceptual structure along which our thoughts must proceed [6], [15]. "The reason that insight is possible is because things hang together in nature anyhow. This bearing of one datum, event, or experience upon another is a fundamental property of the phenomenal world and psychology is not the only science which must deal with the facts" [6]. Bragg, speaking of matter, electricity, and energy says: "Nature herself has already chosen units for them. The natural unit does not, of course, bear any exact connection with our own—Nature has chosen to speak in a certain language; we must get to know that language" [9]. When we review the cast and direction of the scientific advances that we have just outlined—how organic and inorganic are being united by modern science—we realize how energy is a basic idiom in which Nature speaks.

Thus, scientists as well as leaders in science education and educational psycholo-

gists accent the need for unification in our science curricula. Further, each of these three sources gives the same unifying concept—the transformation and conservation of energy. How implement this concept throughout the grade range from one to fourteen?

When we relate the energy concept to problems of instruction we note that energy, in the sense interpreted here, is more than a product of mass and velocity. We accept implications of the mutual transformation of the powers of nature and the resultant energy balance of the earth. We recognize the electromagnetic origin of mass. We sense something of the significance of the statement that "the only solution to the problems of physics, as of biology, lies in recognition of an all pervading life" [5].

The author published a study of some educational values of the energy concept in 1935 [7]. This study examined applications in grades one to seven. Since then, investigations have been extended to junior high school, senior high school, and the first two years of college. Six areas of interpretation have resulted. By means of these areas a correlated range of content may be selected and organized for use on all levels. Stated topically, the areas are: (1) The Sun As Source of Energy, (2) Air, Water, and Earth as Transformers of Energy, (3) Green Plants as Transformers of Energy, (4) Sun, Moon, and Stars as Distributors of Energy, (5) Animal Instinct as Adaptation to Energy and (6) Intelligence as Adaptation to Energy.

Why were these areas selected? What is the justification for the sequence?

Investigation reveals that this selection and this sequence provide for a progressive differentiation of the concept of energy transformation. As instruction proceeds through the sequence there is increase in detail and complexity. For example, the meanings comprehended by the topic, "The Sun as Source of Energy" are more general than those comprehended by the topic "The Green Plant as Transformer of Energy" and the meanings comprehended by the latter are more general than those comprehended by the topic "Intelligence as Adaptation to Energy."

Also, this selection and sequence of areas provide for the shifts of reasoning necessitated by use of a unifying concept. The first area provides for one range of application of the concept, the second for another range, the third for another, and so through the six areas. While, therefore, the kinds of experience differ from area to area the integrative concept is correlative and when shift is made there is transposition of reasoning that progressively expands the concept. "It is the highest achievement to be able to restructure in useful ways the basic propositions or axioms on which our logical thought edifices have been erected" [4].

Review of the content of the six areas shows how the concept integrates a range of differentiating experiences.

Area One, "The Sun as Source of Energy," is a consideration of energy systems. Here we have the background of the whole compass of interpretations. Energy exchange throughout the solar system is a major theme and the lessons prepare for a study of interactions of energy and matter.

Area Two, "Air, Water and Earth as Transformers of Energy" extends the consideration to Energy-Matter Systems. Heat is explained as molecular motion produced by radiant energy. The role of matter as heat transformer is prominent in applications of the Carnot-Clausius Law. The experiences are a foundation for a study of life; for heat acting on matter (Earth, Water, and Air) prepares the earth for life.

Energy-Matter-Life Systems are presented in Area Three. The surface of the earth, the rocks, and the minerals are studied in their relation to effects produced by radiant energy and atmospheric forces. Analysis of plant functions reveals persistent coordination as a prime distinguishing characteristic of life [8], [12], [17].

However, manifestations of life require

rhythmical distributions of energy. Accordingly, concepts of diurnal, monthly, and seasonal cycles are introduced in Area Four. "Sun, Moon, and Stars as Distributors of Energy" links the study of lower organic systems (plants) to higher organic systems (animals).

Area Five, "Animal Instinct as Adaptation to Energy" initiates a study of Energy-Matter-Life-Mind Systems. Adaptation is presented as instinctive reaction for conservation of energy. Protective Coloration, Metamorphosis, Migration, Hibernation, Social Life, and Bodily Structure are considered. The animal as oxidizer and the plant as reducer is a major theme. Correlations with Areas Two and Three extend the restrictions, emphasized in Area Two, of the Carnot-Clausius Law when applied to life.

Area Six, like Area Five, considers Energy-Matter-Life-Mind Systems. However, in Area Six, intelligence takes the place of instinct. Here, we present psychological and anthropological concepts that show man's opportunity for controlled direction of energy. Possibilities of improved social action are derived from contrasts between the possibilities of instinct and reason. We approach an understanding of the significance of the statement that "the transformation of the human brain is the greatest transformation since Neanderthal Man" [2]. Problems of human relationship emerge. A major theme is man as formulator of values. Area Six consummates all of the preceding areas and, pointing to an area yet unformulated, identifies evolution with conscious conservation of energy for the betterment of the world and of man.

"Most of us believe, perhaps in large degree intuitively, that there is an underlying, integrating, unifying principle that in some way characterizes the cosmos of which we are a part and makes that cosmos truly a universe. Presumably this principle manifests itself in various ways: in physics, in chemistry, in biology, psychology, sociology, history, philosophy, art, and ethics. The manifestations are diverse, but the administrative principle responsible for these manifestations is presumably one. Just what it is, none of us are sure. But some of us are permitted to search for it. Recent progress in such widely separated fields as nuclear physics and Gestalt psychology give hope that the search may not be in vain. There is much encouragement from those who work out on the far frontiers of knowledge that the basic marching orders for the organization of the universe, including of course the social organization of mankind, are not only very potent and very profound, but also very simple and very meaningful" [10].

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THE SCIENTIFIC METHOD AS APPLIED TO PERSONAL-SOCIAL PROBLEMS

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Why haven't we obtained better results in teaching the scientific method? Why has a method that has revolutionized the world of scientific discovery for the last three hundred years failed to penetrate the daily lives of people? It would seem that a method which has accomplished so much in the work of scientific discovery must have in it something of value to people as a whole.

Science educators for nearly a half century have stressed the importance of the scientific method as a primary objective of science teaching. At first it was generally thought that the scientific method was a concomitant result of a student's experience in a logically organized subject matter field fortified by a series of laboratory exercises. The methodology acquired was then assumed to be a general discipline functional in the solution of all types of problematic situations.

Several decades passed before psychologists established the general principle that if one expects students to develop skill in the use of the scientific method, the skill must be taught directly. In addition, practice in the use of the method must be given in a wide variety of situations if the student is to become really skillful in solving various types of problems. In this same lapse of time many writers expressed the idea that certain "critical attitudes" or "habits of thinking" were related components of the scientific method. The scientific method became recognized not only as a research procedure but also as a series of attitudes that would aid the user to deal more adequately with causal relations between observed facts and a phenomenon.

Within the last ten years there has been a widespread feeling among science teachers that the emphasis upon teaching the scientific method has not produced proportionate results in changing student behavior. The growing recognition of this situation, which to many is a discouraging situation, has lead science teachers to a rethinking of the "scientific method" objective in teaching. Some writers have come to the conclusion there is not really any such thing as a scientific method, except perhaps a problem followed by hard work. Others have come to the conclusions the scientific method is not any *one* method but several methods. At least we are on safer ground if the term scientific *methods* is used. There is a consensus to the effect that the scientific method is not any exact series of steps which must be followed in a sequence if accurate thinking is to be the final result. This has lead to a re-examination of the scientific method both to define further the method and to search for any previously unrecognized factors in the method.

A number of teachers have expressed the opinion that more emphasis should be given to the development of scientific attitudes in students. These teachers tend to feel there is better "transfer" to real life problems in terms of attitudes than in terms of method.

There seem to be some points of general agreement today among science educators in regard to teaching the scientific method and scientific attitudes. First, a knowledge of the scientific method and the ability to apply the method in areas of personal and social concern is an objective of major importance in science teaching at all grade levels. Second, there is some evidence that positive results can be obtained by teachers where student activities are planned specifically to achieve this objective. The major

problem, however, is to discover ways in which a *greater* degree of competency can be obtained in terms of getting students to appreciate and utilize critical methods in the solution of problems of everyday living.

In the following discussion the writer assumes there is educational value to be obtained from the ways in which scientists work. His purpose is to analyze certain more or less unrecognized or under-emphasized limitations in teaching the scientific method as a procedure for the solution of problems of a personal-social nature.

The scientific method is best adapted and has had its greatest success in the area of the experimental sciences. Educators have learned to use the language and to adopt the name of the method without sufficient recognition that it is essentially a laboratory procedure. Most of the laboratory teaching in schools has been related to problem solving in regard to the directly observable and materialistic aspects of our environment. Assumptions have then been made that these same techniques should be equally applicable and successful in dealing with the personal-social needs of students outside of the laboratory. It seems certain the method is not so easily adjustable to the field of personal-social relations. Even scientists are known to lock up the method in their laboratories when out to lunch.

Students need to be made aware of general situations in which the method is appropriate and areas in which it is limited in application. One can be scientific about buying a suitable pair of shoes, but in most instances it is necessary to eliminate the factor of style in order to do so. Most people refuse to accept the alternative. Somewhere in their educational experiences students need to develop a realization that the major problems of everyday concern are not as simple or as direct as those typically encountered in science. Techniques for solving problems in which there is an emotional bias, set, or value concepts involved are of a different type than those found in a laboratory. Teachers today recognize the learning process to be integrally bound up with the student's emotional life, but have taught the scientific method as though the two were divorced.

Personal-social problems encountered in daily living are often very difficult to solve because the individual has no words or symbols with which to define the problem to himself. In this case "X" is not satisfactory. The individual who is physically or mentally ill when asked what is wrong typically answers, "I don't know." The problem is recognized, the ability to define the problem is lacking. The interval between the two steps is characterized by worry, agitation, and frustration. Students are seldom acquainted with these factors when it comes to applying scientific methods to their problems of daily living.

Another weakness in teaching the scientific method is the failure to establish the relationships between the principles of science and the establishment of a hypothesis in problem solving. The first place a student should expect to find a pertinent hypothesis is in his previously learned principles and generalizations of science. A principle may be a conclusion in one situation, but functions as a hypothesis in the next related problematic situation. Imagination and creativeness may also be needed at this point if the hypothesis is to be expanded to a point where it can lead to a positive attack on the problem. Fertility of imagination and an abundance of guesses at truth are among the first prerequisites of discovery. In practice, erroneous guesses are many times as numerous as those which finally prove to be well founded. In the laboratory this is only a part of one of the most stimulating phases of using the scientific method. However, in problems of every day life-keeping health, selecting or advancing in a vocation, developing economic security, buying a home, planting a lawn, feeding the baby, etc.—the average person is either not so fertile in his guesses or is afraid to formulate a hypothesis. Science teachers have not stressed enough that a breadth of principles and knowledge will reduce hypothesis to the place where

it is better than a speculation. This must be done if the average person is to have confidence in the scientific method for everyday use.

The questions of accurate and adequate data in dealing with personal-social problems is especially difficult. Even in technical laboratory work, particularly the biological sciences, these questions are almost impossible to answer. Medical statisticians have spent years trying to determine the number of cases in which a new drug must be tried before it can be said to be "safe" treatment. Similarly, how much and what kind of data does a student need to determine whether he has made the best choice of action for himself? In problems of this type, and many others of human concern, action must be based upon recognized incomplete data. The problem is really not solved, but nevertheless the individual is forced into action. In the field of technical science, judgment and action would be withheld until further data were presented.

The so-called "conclusions" to a personal-social problem is in reality only an intelligent plan or guide for action. The student brings his accumulated knowledges and experiences to focus upon a situation for the purpose of making a choice of action. As he acts upon the problem he is regarded as being scientific in his procedure if he willingly seeks to incorporate new data into his thinking. Thus the scientific method in regard to personal-social problems leads to a progressive type of solution. At other times the so-called conclusion is actually only an increased understanding of the problem. Too much emphasis has been placed on the "solving" aspect of the scientific method in dealing with personal-social problems. Conclusions are probably best thought of as invitations to further research leading to an increased understanding or the expansion of a concept. Solutions to problems of everyday living are on various maturity levels, and therefore, the problems are never actually solved except perhaps in terms of a particular moment. The study of the scientific method in most science courses does not leave the student with this impression.

The verification of experiment so essential in scientific investigation cannot be applied in many fields of investigation involving man. No problem or situation is ever actually duplicated or repeated in man's experience, even under the best of laboratory conditions. Yet we teach students a method, the very essence of which is that a situation can be duplicated and verified, not only by the original investigator, but by any other investigators under identical conditions. However, there are no identical situations in personal-social experiences. At best a verification of a conclusion in regard to a problem found in daily living can be nothing more than a willingness to reexamine the original data when a similar problem presents itself. One should *not* expect previously formed conclusions will necessarily prove satisfactory another time in problems of daily living.

At this point one may well raise the question as to what are we going to do in regard to teaching the scientific method? How can the scientific method be successfully incorporated into the thinking life of the average citizen? As previously indicated, the scientific method is an experimental laboratory method and is best suited to the solution of problems of living things only with great difficulty and even then only in a limited degree.

It is because the test of experiment cannot be applied in many of the fields of human investigation that our knowledge remains so uncertain in these fields. Many science teachers have not pointed out these limitations in teaching the scientific method as a method of approach in the solution of personal-social problems. A student's failure to apply the scientific method in daily living has not been entirely his fault or the fault of the teaching—the method does not "apply" in the type of problem with which the student is faced from day to day outside of class.

There is no immediate solution regarding the use of the scientific method in regard to personal-social problems. Probably a primary step in re-thinking this objective in science teaching is to stop debating "the number or sequence of steps" or "whether there is any such method" or "whether scientists really use such a method," and investigate methods people use in solving problems of daily concern. What procedures are followed that lead people to generally satisfactory conclusions and what procedures are followed by people who are failing to solve their problems? Undoubtedly many procedures and methods of thinking used typically by scientists are involved, but not all of them, nor in the same way.

There is much to teach about accurate reasoning and critical attitudes of approach in regard to problems of daily living. The scientific method has much to offer as an example of an applied method based upon accurate data and exeprimentation. However, it needs considerable reinterpretation to be adaptable to personal-social problems.

PREDICTING BIOLOGY REGENTS GRADES FROM PERSONALITY OF NINTH-YEAR STUDENTS *

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Principals, deans of boys and girls, and all others interested in the proper guidance of our secondary-school youth, have long been cognizant of the fact that many students do not achieve scholastic success commensurate to the I.Q. Many students with comparable I.Q.'s fail in certain subject areas while taking scholastic honors in others. Evidently, there is something other than I.Q., that determines whether *Mary Jane,* or *John Doe,* will become more proficient in one subject than in another. Dillingham [19], Karlan [26], Preische [30], Smith [33], Billig [49], Cattell [52], and Greenwood [55], among other investigators, have stressed the fact that personality factors, more so than I.Q., determine whether an individual will succeed in a particular line of endeavor.

The study of the relation of personality to achievement is not new. In the related studies made during the past decade, the emphasis has been to determine the factors affecting school achievement. An analysis of several of those studies, however, reveals conflicting findings as to the relation between certain personality components and school achievement.

At the high-school level, three studies [21, 32, 54] find no, or insignificant, positive correlations between personality and achievement. The instrument used in each case was the Bernreuter Personality Inventory purporting to measure six areas of personality: Neurotic Tendency, Self-Sufficiency, Introversion-Extroversion, Dominance-Submission, Sociability, Confidence.

Measuring some of the same areas of personality but using different instruments, several investigators have disclosed opposing findings which in themselves are conflicting. Considering "extroversion" at the college level, one study [41] finds underachievers better adjusted whereas another study [45] finds half of the failures in this group. As opposed, there is a study [12] at the elementary level in which a positive correlation is found with general achievement for boys and unrelated as concerning girls.

Beauchamp [11] found traits of favor-

* Based on a doctoral dissertation entitled *Relation of Certain Personality Components to Achievement in Secondary School Science,* Henry Gould, 1951. Copies are on file in the library of School of Education, New York University, New York, New York.

able mental hygienic value to be associated with high science scores on the elementary-school level whereas Bender [36] found submissiveness prevalent among those of the highest scholarship at the college level.

While Hughes [24], measuring twelve different traits, found students (secondary level) with highest honors very superior in the traits measured, Musselman [28] found students with the highest achievement ratio (secondary level) to have the poorest personality adjustment. At the elementary level, one study [13] shows students scoring consistently lower in social studies to be maladjusted students, yet another study [14] using the Bell Adjustment Inventory, reveals 46 per cent of pupils in a typical classroom likely to have unfavorable ratings in more than one area.

Although the above evidence is conflicting, Bradenburg [37] has found a closer relationship existing between personality status and grades than between I.Q. and grades (college level), and Tyler [44], working at the same level, found that intelligence alone does not guarantee successful undergraduate work.

If I.Q. is not the determining factor predicting possible achievement in school, the task remains to determine that factor or combination of factors in the total personality which would have a more reliable prognostic value.

Thorpe [60] reports that in so far as investigators have gone in measuring personality traits, they have found a decided tendency for favorable traits to be associated together in an individual and that ". . . desirable traits tend to be found together in the mesh of personality" [60:305]. If the foregoing statement is valid then, perhaps, there may be certain components having a tendency to be grouped together in the mesh of personality of *science students* and to be lacking in the personality of non-science students. The present investigation, therefore, seeks to determine whether a distinctive pattern of certain components of personality is prevalent among high-school students who elect biology as a major subject, and is lacking among those who do not elect biology as a major subject.

SUBJECTS

The entire ninth-year class (157 boys and girls) attending the Ossining, New York, Junior-Senior High School during the 1946–47 school year. All of these students had completed one year of "General Science."

MEASURING INSTRUMENTS USED

Bell Adjustment Inventory; Bernreuter Personality Inventory; Mental Health Analysis; Otis Quick-Scoring Mental Ability Test, Gamma, Form BM; A.C.E. Cooperative Science Test for Grades 7, 8, and 9, Form R; June 1948 Biology Regents Examination; Teachers' Final Grades as recorded for 1947–48 School Year.

PERSONALITY [1] TRAITS MEASURED

Since the term "personality" is subject to diversified interpretations, no attempt was made to investigate all the possible traits that compose individuals. Neither does this investigator maintain that the personality components used in this investigation are separate entities which could be pigeon-holed into individual compartments. The following components were chosen, rather, as representing only a few of the multitude of factors that might possibly have an effect on the integrated organism:

(a) Health Adjustment
(b) Home Adjustment
(c) Social Adjustment
(d) Emotional Adjustment
(e) Neurotic Tendency
(f) Self-Sufficiency
(g) Introversion-Extroversion
(h) Dominance-Submission
(i) Confidence
(j) Sociability
(k) Behavioral Immaturity
(l) Emotional Instability

[1] "Personality," as used in this study, refers to the living organism-as-a-whole as it is affected by, and responds to, its external and internal environment.

(m) Feelings of Inadequacy
(n) Physical Defects
(o) Nervous Manifestations
(p) Close Personal Relationships
(q) Interpersonal Skills
(r) Social Participation
(s) Satisfying Work and Recreation
(t) Adequate Outlook and Goals

SUB-PROBLEMS INVOLVED

Any data pertinent to the major problem of this research evolves from the solution of the following subsidiary problems:

1. The relationship between students' intelligence quotient and achievement in general science
2. The relationship between students' intelligence quotient and each of the twenty personality components considered in this study
3. The relationship between achievement in general science and each of the twenty personality components
4. The relationship between achievement in biology and each of the twenty personality components
5. The relationship between achievement in a non-science-major subject and those factors of the personality found to be significant in "3" and "4" above

GENERAL PROCEDURE

All raw scores were converted into T-scores. The product-moment method was used to calculate coefficients of intercorrelation for the twenty personality components purported to be measured by the personality inventories. In addition, coefficients of correlation were calculated between each of the personality components and the following criteria: I.Q., general science, non-science, and biology achievement scores. The foregoing criteria were intercorrelated.

Multiple R's were calculated, by the Doolittle Method, between the personality components and I.Q. scores, and between the personality components (with and without the inclusion of I.Q.) and each of the criteria: general science, non-science, and biology achievement scores.

Best-fitting multiple R's were calculated, by the Wherry-Doolittle Test-Selection Method, between the personality components and the criteria: general science, non-science, and biology achievement scores.

All multiple R's were corrected for chance errors. Regression equations were calculated wherever feasible.

All findings were arbitrarily selected at the 1 per cent level of confidence when tested against the Null hypothesis.

The reliability of the compared groups was tested by means of critical ratios calculated for the difference between the means. Also employed was the "z" test of differences between two "r's" having one variable in common.

RELATIONSHIP BETWEEN STUDENTS' INTELLIGENCE QUOTIENT AND ACHIEVEMENT IN GENERAL SCIENCE

Since "intelligence" represents one of the major factors intended to be held constant during the greater portion of this research project, it was necessary to determine whether any signficant difference existed between the I.Q.'s of the boys and girls and whether the I.Q.'s of both groups differed significantly from national norms. In Table I the students are classified on the basis of Very Superior (120-129), Superior (110-119), Average (90-109), Dull Average (80-89), and Borderline (70-79). An analysis of the data discloses close approximations on the Very Superior and Borderline levels between the two groups. On the Superior and Dull Average levels the per cent of boys exceeds that of the girls, whereas on the Average level the per cent of girls exceeds that of the boys. The total per cent distribution approxi-

TABLE I

Distribution of I.Q. Values

	Frequency		Per Cent	
Range	Boys	Girls	Tot.	Nat'l
120–129	5.5	4.4	4.9	8
110–119	16.3	11.6	14.3	16
90–109	59.7	69.5	63.9	46
80–89	15.3	10.2	13.1	16
70–79	3.3	4.4	3.7	8
Totals	100	100	100	94

mates that of a normal curve with only the Average students exceeding the per cent found on a national norm.

For 157 cases, a critical ratio would have to approximate 1.976 to be accepted at the 5 per cent level of confidence [3:610]. From the data prepared for Table I a critical ratio of 1.28 was calculated for the difference between the means. Since this figure is not statistically significant at the 5 per cent level of confidence we can accept the Null hypothesis that there is no significant difference between the true means of the samples we are comparing and we can assume that they come from the same population. On the basis of the critical ratio obtained, no differentiation as to sex was made in computing the correlation with achievement in general science as reported in Table III.

ACHIEVEMENT IN GENERAL SCIENCE

In studying the achievement of eighth-grade pupils in general science, Beauchamp [11:203] found that, in general, there were more girls than boys in the groups that were average and in the groups that were inferior in general science achievement. This is not borne out in the groups used in the present study as revealed by the data in Table II. In the interval 85–94 which contains the mean score (91.57) for the boys, there were found approximately ten per cent of the boys and twelve per cent of the girls. The mean score (83.85) for the girls is included in the interval 75–84 which includes approximately nine per cent of the boys and twenty-two per cent of the girls. The mean (88.26) for both boys and girls, included in the interval 85–94, comprised approximately the same per cent of each sex. In agreement with Beauchamp are the findings, which show more boys than girls in the groups superior in general science. The boys comprised 18.4 per cent, and the girls only 8.8 per cent, of the cases lying above one sigma from the mean (i.e. above 113.79) of the entire distribution of the scores. However, in the groups located below one sigma from the mean (i.e., below 62.73) of the general distribution of the scores, there were approximately the same percentage of each sex: 21 per cent of the boys and 19 per cent of the girls. On the

TABLE II

RAW SCORES OBTAINED BY NINTH-YEAR STUDENTS ON COOPERATIVE SCIENCE TEST FOR GRADES 7, 8, AND 9, FORM R

Range	Frequency			% Frequency			Cumulative % Frequency		
	Boys	Girls	T	Boys	Girls	T	Boys	Girls	T
135–144	4	1	5	4.3	1.5	3.1	100	100	100
125–134	7	1	8	7.6	1.5	5.0	95.6	98.6	96.8
115–124	6	4	10	6.5	5.8	6.2	88.0	97.1	91.8
105–114	18	3	21	19.6	4.4	13.0	81.5	91.3	85.6
95–104	14	15	29	15.2	21.7	18.0	61.9	86.9	72.6
85–94	9	8	17	9.8	11.6	10.6	46.7	65.2	54.6
75–84	8	15	23	8.7	21.7	14.3	36.9	53.6	44.0
65–74	7	9	16	7.6	13.0	9.9	28.2	31.9	29.7
55–64	8	8	16	8.7	11.6	9.9	20.6	18.9	19.8
45–54	6	3	9	6.5	4.4	5.6	11.9	7.3	9.9
35–44	4		4	4.3		2.5	5.4	2.9	4.3
25–34		2	2		2.9	1.2	1.1	2.9	1.8
15–24	1		1	1.1		.6	1.1		.6
Totals	92	69	161	100	100	100			
Median	97.1	83.3	90.6						
Mean	91.6	83.88	88.26						
σ	27.61	21.70	25.53						
σ_M	2.878	2.612	2.012						

Standard error of difference between the two means: 3.89

Critical ratio: 1.98

basis of the calculated critical ratio one cannot, with too great assurance, infer that a true difference exists between the two groups with reference to achievement in general science.

I.Q. AND GENERAL SCIENCE ACHIEVEMENT

Many studies have been made showing the relationships between intelligence quotient and achievement in school subjects. Those reported in Table III were concerned

TABLE III

Coefficients of Correlation Between Intelligence Quotients and Achievement In School Subjects as Determined by Several Investigators

Investigator	School Subject Correlated	r
Feingold	General Science	.76
Gould	General Science	.75
Dickinson	Science	.67
Jordan	General Science	.64
Dillingham	Scholarship	.56 .52
Bond	Biology	.54
Spinelle	Honor point average	.50
Turney	All subjects	.50
Preische	Physics Regents	.48
Heiss	General Science	.48

with either the elementary or secondary level and reveal indices of forecasting efficiency

$$(E = 1 - \sqrt{1 - r^2})$$

ranging from a low of approximately 12 per cent to a high of approximately 35 per cent. Since the correlation must be above .87 for a test's forecasting efficiency to be greater than 50 per cent (2:337), and since the estimation of an individual's score in one test from another is not warranted unless "r" is at least .90 [2:336], the evidence, as at present available, does not warrant the use of "I.Q." as the sole measure of predicting achievement in general science.

The wide variances of the "r" revealed in the above table are possibly accounted for, in some degree, by the fact that not only were different intelligence tests used but, in addition, different tests for achievement and, also, that the tests were administered to students on different educational levels.

Feingold [22:455–67] included general science as one of the correlating factors in his study with 76 high-school students in obtaining his correlation of .759 between intelligence and achievement in general science.

Primarily interested in the relation of reading ability to scholastic achievement, Dickinson [18:616–26] used 149 pupils in the 8th, 9th, and 10th grades when his correlation of .666 between science and intelligence was obtained.

Using four intelligence tests with 32 pupils in general science, Jordan's [25:419–29] correlation was .636 for the Terman test.

Dillingham [19:66] tested 195 boys and 215 girls, and used the Terman Group Test of Mental Ability Form A with those students whose I.Q.'s had not been previously determined by either this test or by Form B of the Otis Self-Administering Test of Mental Ability. His study, on the high-school level, revealed correlations between intelligence and general scholarship to be .515 for the boys and .556 for the girls.

With the Stanford-Binet as a measuring instrument for determining intelligence, Bond [16:29] found an "r" of .54 with achievement in tenth-grade biology.

Preische [30:52] correlated intelligence with both teachers' and Regents' marks in physics and obtained correlations of .45 and .48 respectively.

While determining the relation of personality test scores to school marks and intelligence quotients, Spinelle [34:289–94] found, on the junior-high-school level, correlations of .50 between intelligence and academic honor-point average.

Administering the Powers General Science Test, Forms A and B, to 400 ninth-grade general science students who were grouped according to their scores on the Terman Group Test of Mental Ability,

Heiss [23:479–84] disclosed a correlation of .48 which he considered a marked relationship.

Finally, Turney [35:129] tabulated the results of 28 experiments measuring the relation of the intelligence to high-school grades and found that the median correlation was approximately .50 for all studies.

The present investigator, using 92 boys and 69 girls, obtained a correlation of .75 for both boys and girls between intelligence quotients and achievement in general science. The "t" value of 14.30 makes this correlation highly significant beyond the 1 per cent level of confidence.

THE RELATIONSHIP BETWEEN STUDENTS' INTELLIGENCE QUOTIENT AND EACH OF THE TWENTY PERSONALITY COMPONENTS CONSIDERED IN THIS STUDY

In order that all the scores would be positive, expressed in terms of the same units, and represent equivalent scores in a normal distribution, the 3,341 raw scores calculated for this part of the investigation were converted into T-scores [2:149–55].

The product-moment method of correlation was employed to determine the relationship between students' intelligence quotient and each of the twenty personality components. In the same manner, the interrelationships between the twenty personality components were ascertained.

In order to ascertain the proportion of variance in *Intelligence Quotient* that is dependent upon or predicted by the combined twenty personality components, a *coefficient of multiple determination (R^2)*, was calculated by the Doolittle Method [3:441–7]. In addition, a *multiple R* was calculated and corrected for chance errors.

An adequate analysis of the 210 intercorrelations shown in Table IV necessitates a breakdown of the data into smaller units for consideration. Unfortunately, space limitations do no permit a detailed presentation here and the reader is referred elsewhere [2] for this information. The following summary, however, presents pertinent findings.

[2] See pp. 31–76 of dissertation.

TABLE IV

Intercorrelations of T-Scores Between Intelligence Quotients and Twenty Personality Components (N=157)

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	M	σ
C	-13	-17	-28	-12	-14	+11	-12	+22	-17	+06	+27	+20	+38	+21	+04	+22	+21	+27	+22	+31	50.31	9.69
a		+40	+41	+61	+38	-26	+48	-29	+47	+08	-37	-57	-42	-28	-55	-46	-16	-17	-33	-13	50.24	10.50
b			+39	+55	+36	-26	+43	-24	+43	+01	-26	-48	-45	-36	-63	-18	-13	-24	-23	-06	49.82	9.75
c				+54	+69	-24	+63	-64	+71	+24	-27	-59	-49	-16	-41	-38	-36	-58	-44	-12	50.40	8.70
d					+61	-26	+73	-35	+66	+25	-28	-67	-45	-31	-59	-15	-07	-15	-22	-08	50.25	9.72
e						-26	+90	-63	+87	+34	-23	-58	+35	-09	-48	-12	-10	-23	-10	-09	49.77	10.13
f							-31	+34	-45	+49	+15	+22	+15	+06	+24	+06	+13	+02	+30	+11	49.98	10.11
g								-54	+88	+41	-30	-65	-40	-07	-58	-14	-07	-22	-26	-13	50.43	9.98
h									-75	+10	+19	+41	+34	+06	+32	+25	+20	+43	+32	+09	50.11	9.82
i										+11	-29	-64	-45	-15	-56	-19	-13	-33	-32	-14	50.14	10.11
j											-02	-13	-02	-07	-12	-03	+05	-04	+07	+05	50.20	10.26
k												+52	+50	+21	+40	+26	+33	+37	+23	+33	49.78	9.76
l													+62	+15	+68	+31	+22	+34	+35	+23	49.55	9.71
m														+37	+51	+39	+27	+43	+34	+23	50.10	9.67
n															+37	+22	+05	+12	+16	+18	49.01	7.94
o																+23	+13	+26	+31	+06	49.14	9.01
p																	+49	+51	+46	+31	49.72	9.59
q																		+47	+38	+42	49.43	9.91
r																			+42	+29	49.85	9.91
s																				+36	49.59	9.89
t																					49.62	9.71

LEGEND:

C – Intelligence Quotients (IQs)

a – Home Adjustment; b – Health Adjustment; c – Social Adjustment; d – Emotional Adjust. — Data from Bell Adjust. Inventory

e – Neurotic Tendency; f – Self-Sufficiency; g – Introversion-Extroversion; h – Dominance-Submission; i – Confidence; j – Sociability — Data from Bernreuter Personality Inventory

k – Behavioral Immaturity; l – Emotional Instability; m – Feelings of Inadequacy; n – Physical Defects; o – Nervous Manifestations; p – Close Personal Relationships; q – Interpersonal Skills; r – Social Participation; s – Satisfying Work & Recreation; t – Adequate Outlook and Goals — Data from Mental Health Analysis Secondary Series: Form A

SUMMARY OF FINDINGS DEALING WITH INTERRELATIONS

Calculated coefficients of intercorrelation on the Bell Adjustment Inventory for the subjects used in this study were much higher than those reported by Bell between *Home* and *Social Adjustment,* and between *Home* and *Emotional Adjustment.*

All of the Bell intercorrelations were statistically significant at the 1 per cent level of confidence.

Calculated coefficients of intercorrelation between the various scales of the Bernreuter Personality Inventory are in high agreement with those reported by Bernreuter. Exact agreements were found in two instances: *Self-Sufficiency* and *Introversion-Extroversion, Confidence* and *Sociability.* A difference of .02 to .03 was found in four correlations. The remaining nine intercorrelations showed negligible differences ranging from .05 to .17 with those reported by Bernreuter.

With the exception of the correlations between "Dominance-Submission" and "Sociability," an between "Confidence" and "Sociability," both of which are statistically insignificant at the 5 per cent level of confidence, the remaining 13 Bernreuter intercorrelations were found to be significant at the 1 per cent level of confidence.

Intercorrelations between the calculated scores on the Bell and Bernreuter instruments show a lack of statistical significance at the 5 per cent level of confidence for two correlations: "Home Adjustment" and "Sociability," and "Health Adjustment" and "Sociability." The remaining 22 "r's" were found to be statistically significant at the 1 per cent level of confidence.

On the basis of the personality components which they purport to measure, the Bell Adjustment Inventory and the Bernreuter Personality Inventory show substantial relationships among the following components: Bell's "Social" and "Emotional" adjustments and Bernreuter's "Confidence," "Neurotic Tendency," "Introversion-Extroversion," and "Dominance-Submission."

Of the 45 intercorrelations calculated on the Mental Health Analysis, two correlations were statistically insignificant at the 5 per cent level of confidence; 5 correlations were significant at the 5 per cent level of confidence; 38 correlations were significant at the 1 per cent level of confidence.

A comparison of the raw scores calculated on the Mental Health Analysis with the national norms as reported by the authors of the *Analysis* shows that the subjects of this investigation fall on the 70th percentile in two categories, on the 60th percentile in three categories, and on the 50th percentile in five categories. In no instance did they fall below the 50th percentile for either "assets" or "liabilities."

Of the forty intercorrelations calculated between the Bell Adjustment Inventory and the Mental Health Analysis, 28 were found to be significant at the 1 per cent level of confidence, four were significant at the 5 per cent level, and eight were statistically insignificant at the 5 per cent level of confidence.

Of the ten categories measured by the Mental Health Analysis, "Adequate Outlook and Goals" was the only category lacking significant statistical relationship with Bell "Adjustments."

Of the sixty intercorrelations between the Mental Health Analysis and the Bernreuter Personality Inventory, 31 were statistically *insignificant* at the 5 per cent level, three were significant at the 5 per cent level, and 26 correlations were significant at the 1 per cent level of confidence. Correlations calculated between "Feelings of Inadequacy" and "Neurotic Tendency," "Satisfying Work and Recreation" and "Self-Sufficiency," "Nervous Manifestations" and "Self-Sufficiency," and between "Emotional Instability" and "Self-Sufficiency" do not agree, in interpretation, with expectations based on the remaining intercorrelations where these categories were used.

Of the 124 intercorrelations calculated between the Bell Adjustment Inventory, Bernreuter Personality Inventory, and Mental Health Analysis, only 36, or 29 per cent of the total number, were substantial (or better) relationships. Intercorrelations found to be statistically insignificant at the 5 per cent level of confidence totaled 41 in number, or 33 per cent of the total number of intercorrelations.

Of the 29 per cent of the intercorrelations found to be substantial (or better), those between the Bell Adjustment Inventory and the Mental Health Analysis contributed 12 per cent.

Of the 33 per cent of the intercorrelations found to be statistically insignificant at the 5 per cent level of confidence, those between the Bernreuter Personality Inventory and the Mental Health Analysis contributed 25 per cent.

Only fourteen of the twenty personality components used in this investigation appear in the 36 correlations showing a high degree of relationship. They include all four of the Bell "adjustments," six of the ten Mental Health "categories," and four of the six Bernreuter "traits." The Bernreuter exclusions are: *Self-Sufficiency* and *Sociability*. Those excluded from the Mental Health Analysis are: *Behavioral Immaturity, Physical Defects, Interpersonal Skills,* and *Adequate Outlook and Goals.*

The number of times each of the fourteen personality components, mentioned in the above paragraph, appear in the 36 correlations showing a high degree of relationship are: Social Adjustment, 9; Emotional Instability, 8; Nervous Manifestations, 7; Introversion-Extroversion, 7; Confidence, 7; Emotional Adjustment, 6; Feelings of Inadequacy, 6; Home Adjustment, 6; Health Adjustment, 5; Neurotic Tendency, 4; Dominance-Submission, 3; Social Participation, 2; Close Personal Relationships, 1; Satisfying Work and Recreation, 1.

On the basis of the findings, the fourteen personality components mentioned above were used to represent the over all picture of the personality components prevalent among the 157 ninth-year students who were finally used as subjects in this investigation.

The correlation coefficients between Intelligence Quotient scores and the twenty personality components are presented in Table V below. For an explanation of column headings the reader is referred to any standard text on educational statistics.

On the basis of the "t" values, only the first ten components show a definite relationship at the 1 per cent level of confidence, and only to a small degree. In spite of the fact that the small correlations may merely mean that the measurement situation is contaminated by many things uncontrolled or not held constant [3:166], the supporting evidence does not justify the consideration of any of the ten correlations as predictive indices for the determination of I.Q. scores. An "r" of .3 and an "E" of 4.6 usually represent the lowest level of validity coefficients found for useful predictive instruments in psychological and educational practice [3:410–11]. The components "m" and "t" are the only two that satisfy these criteria. However, their respective low "r^2" values of 14.44 per cent and 9.61 per cent, and their respective low "E" values of 7.5 and 4.93, make it doubtful that the use of these two personality components, as predictive indices of I.Q. scores, would be of any value since the efficiency of prediction based upon the average unsystematic interview might reach 5 per cent [3:410].

Further analysis of the data in Table V reveals that, of the four components rated by the Bell Adjustment Inventory, only "Social Adjustment" (c) shows a statistical significant relationship at the 1 per cent level of confidence. The calculated "r" of —.28 indicates that, on the basis of this investigation, those students with social maladjustments tend to have lower I.Q. scores. This finding is in agreement with Meyer [14] who used the same measuring instrument. He reports [14:65–7] that adjustments in the social area seem to dis-

TABLE V

COEFFICIENTS OF CORRELATION BETWEEN INTELLIGENCE QUOTIENTS AND TWENTY PERSONALITY COMPONENTS RANKED IN DESCENDING ORDER OF "t" VALUES

Code	(1) N	(2) "t"	(3) r	(4) σ^r	(5) r^2	(6) k^2	(7) k	(8) E
m	157	5.115	.38	.07	.1444	.8556	.9250	.0750
t	157	4.060	.31	.07	.0961	.9039	.9507	.0493
c	161	3.678	—.28	.07	.0784	.9216	.9600	.0400
k	157	3.491	.27	.07	.0729	.9271	.9629	.0371
r	157	3.491	.27	.07	.0729	.9271	.9629	.0371
h	161	2.844	.22	.07	.0484	.9516	.9755	.0245
p	157	2.808	.22	.08	.0484	.9516	.9755	.0245
s	157	2.808	.22	.08	.0484	.9516	.9755	.0245
q	157	2.674	.21	.08	.0441	.9559	.9777	.0223
n	157	2.674	.21	.08	.0441	.9559	.9777	.0223
l	157	2.541	.20	.08	.0400	.9600	.9798	.0202
b	161	2.175	.17	.08	.0289	.9711	.9854	.0146
i	161	2.175	—.17	.08	.0289	.9711	.9854	.0146
e	161	1.783	—.14	.08	.0196	.9804	.9902	.0098
a	161	1.653	—.13	.08	.0169	.9831	.9915	.0085
d	161	1.524	—.12	.08	.0144	.9856	.9928	.0072
g	161	1.524	—.12	.08	.0144	.9856	.9928	.0072
f	161	1.396	.11	.08	.0121	.9879	.9939	.0061
j	161	.758	.06	.08	.0036	.9964	.9982	.0018
o	157	.498	.04	.08	.0016	.9984	.9992	.0008

Letters in the column "Code" refer to the legend in Table IV.

criminate most reliably in terms of intelligence for boys, and that there is a general trend for the brighter students to respond with fewer answers indicating maladjustment. Dillingham [19], using the Washburne Social Adjustment Inventory, obtained a correlation of .301 for girls between social adjustment and intelligence.

Of the six personality components rated by the Bernreuter Personality Inventory, only "Dominance-Submission" (h) shows a statistical significance at the 1 per cent level of confidence. The calculated "r" of .22 indicates that the brighter students tend to dominate others in a face-to-face situation. Since dominance is an attribute associated with people having extrovertive tendencies one would expect correlations with this latter trait. The evidence, however, appears to be conflicting. In this investigation, as revealed by the data in Table V, Introversion-Extroversion (g) shows a correlation of —.12 with I.Q. scores. Interpreted, this means that those students having a tendency to be introvertive obtain low scores on the Otis test. While this is in agreement with the finding above, it does not show as high a correlation. Stagner [43] found a correlation of .161 with Bernreuter's "Introversion-Extroversion" and an "r" of .159 with "Dominance-Submission" when correlating with I.Q., using college freshmen as subjects. Hendrickson [12], using students in the fifth and sixth grades, found extroversion to be negatively related to intelligence for boys and practically unrelated in the case of girls. On the college level, Bender [36] found no significant correlation between scores on an ascendance test and I.Q. scores. Nemzek [29] used the Bernreuter Personality Inventory with sophomore students at the University of Minnesota High School and obtained correlations between "Dominance-Submission" and "I.Q." that are greatly in variance with the above mentioned studies, namely: —.088 for boys; .095 for girls.

Eight of the ten correlations found in Table V to be statistically significant at the 1 per cent level of confidence, were calculated with the traits measured by the Mental Health Analysis. They were: Feelings of Inadequacy, Adequate Outlook

and Goals, Behavioral Immaturity, Social Participation, Close Personal Relationships, Satisfying Work and Recreation, Interpersonal Skills, and Physical Defects. Since the first two are the only ones that might possibly be used as predictive indices they are interpreted as follows:

> On the basis of this investigation, those students with high I.Q. scores *do not* feel inferior and incompetent. They have a satisfying philosophy of life that guides their behavior in harmony with socially acceptable, ethical, and moral principles. They establish approved personal goals and make reasonable progress toward their attainment [61].

Cattell [52] has stated that intelligence appears as a general factor "B" among personality traits, and that it correlates to the extent of about .3 with a distinct factor "C" of emotional stability. The present investigation is in agreement to the extent that the calculated coefficient of correlation of .27 between "Behavioral Immaturity" (k) and "I.Q." indicates that those students who are emotionally stable tend to achieve high I.Q. scores on the Otis test.

THE MULTIPLE R

The data presented in the preceding pages have revealed that no one of the twenty personality components, used by itself, is a good predictive index of I.Q. scores. In addition, it has been disclosed that considerable overlapping exists among the twenty measured personality components and hence duplication of one another to some extent. In view of the foregoing, the problem is to find a system of weights that will produce a composite correlating more highly with I.Q. than any *one* of the twenty personality components. To find this composite, a coefficient of multiple determination (R^2) was calculated [3:445].

It has been a common finding that it rarely pays to bring into a multiple-prediction situation more than four or five variables. An attempt to use the Wherry-Doolittle Test Selection Method [2:435–51], for selecting those personality components that would best predict I.Q. scores, had to be abandoned after the selection of only two components. A possible explanation for the inadequacy of this method for the purposes of the present investigation is offered by Stead [9:245] who states that the Wherry-Doolittle Test Selection Method will not hold if two tests having some part in common, and thus present spurious correlation, are included in the original set of tests. The fact that the tests used do have some parts in common has been adequately revealed by the data.

If, as Wechsler is reported [8] to have said, intelligence includes one's personality as a whole, and if the instruments used in this investigation do measure certain aspects of the total personality, then it should be possible by means of the Doolittle Method [3:441–7] to determine the contributions made by each of the twenty personality components to I.Q. scores.

The data in Table IV reveal that the single correlation between component "m" and I.Q. scores was .38, that it (Table V) accounted for 14.44 per cent of the variance associated with I.Q. scores, and that its index of forecasting efficiency was 7.5 per cent. By using the Doolittle Method, the coefficient of multiple correlation (for the twenty components) was calculated as .497 which, when corrected for chance errors, reduces to .378. This latter figure is similar to that calculated for the single correlation between component "m" and I.Q. scores.

On the basis of the foregoing findings, one can conclude that the twenty personality components are not measuring, to any great extent, the same aspects of the total personality that are measured by the I.Q. scores. The latter should, therefore, be considered as one of the independent variables in the solution of the remaining subproblems of this investigation.

An attempt to find a "best-fitting" maximum R between the personality components and I.Q. scores resulted in the combination shown in the following table.

[8] L. Freeman, "Wider Test Urged for Intelligence," *New York Times*, September 6, 1949, p. 30.

TABLE VI

CALCULATIONS OF A MULTIPLE R BETWEEN SIX PERSONALITY COMPONENTS AND SCORES ON I.Q. TEST (N=157)

Variables	B_{1k}	r_{1k}	$B_{1k}r_{1k}$
X_4 Social adjustment	—.2329	—.28	.065212
X_8 Introversion-extroversion	.1622	—.12	—.019464
X_9 Dominance-submission	.1053	.22	.023166
X_{12} Behavioral immaturity	.1376	.27	.037152
X_{15} Physical defects	.1077	.21	.022617
X_{21} Adequate outlook and goals	.2288	.31	.070928
			$R_2=.199611$
			$R=.447$

Although the R^2 and the R shown in the above table are both lower than those reported by the use of the twenty components, when corrected for chance errors the values become: $_cR^2=.1676$, and $_cR=.409$. Interpreted, the data disclose that the six personality components, combined, account for approximately 17 per cent of the variance of I.Q. scores. The multiple R indicates that I.Q. scores predicted on the basis of a multiple regression equation employing the above six personality components would correlate to the extent of .41 with actual scores.

Since only 17 per cent of the variance associated with I.Q. scores has been accounted for by the instruments used in this part of the investigation, it remains the task of some other investigator to determine other personality components that might be used as predictive indices.

RELATIONSHIP BETWEEN PERSONALITY COMPONENTS AND ACHIEVEMENT IN GENERAL SCIENCE AND NON-SCIENCE

This part of the investigation is concerned with those students who, at the completion of their ninth-year of school did not elect an advanced science subject for their tenth year.

Since some students excel in one subject and do poorly in another, teachers' "final grade" as recorded on permanent office records cards for all subjects at the end of the tenth-year of school were averaged for the students used as subjects in this part of the study. The average "final grade" was used as an index of achievement in a non-science-major subject, converted into "T-scores," and correlated with each of the variables previously investigated.

Since the treatment of the data for this part of the investigation was similar to that previously used, only Figure 1 is introduced for a visual presentation of the contributions made by the personality components to the two criteria. And, since space limitations prevent a more adequate discussion only the summary of findings is presented below.

SUMMARY OF FINDINGS

GENERAL SCIENCE AND PERSONALITY

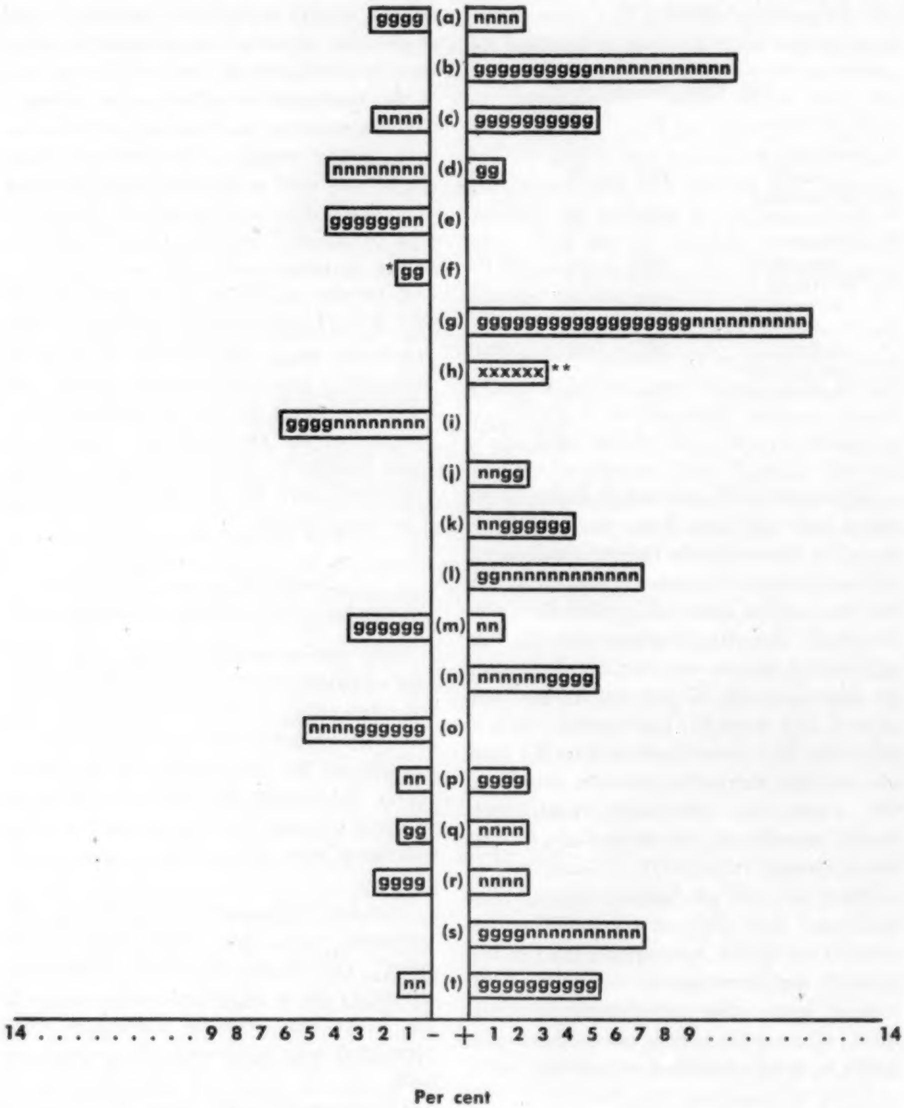
Only one personality component, "Feelings of Inadequacy" (m), shows a substantial relationship of .41 when correlated with achievement scores in general science.

None of the components of the Bernreuter Personality Inventory is significant at the 1 per cent level of confidence when correlated with achievement in general science.

"Health Adjustment" (b), "Social Adjustment" (c), and "Emotional Adjustment" (d) from the Bell Adjustment Inventory show significant relationships at the 1 per cent level of confidence when correlated with achievement in general science.

The Mental Health Analysis contributes six personality components that are significant at the 1 per cent level of confidence when correlated with achievement in general science. They are: Feelings of Inadequacy (m), Adequate Outlook and Goals (t), Satisfying Work and Recreation (s), Behavioral Immaturity (k), Physical Defects (n), and Emotional Instability (l).

On the basis of the "z" test of differences between "r's," no significant statistical dif-



Scale: . . = 1 per cent **Legend** gg **Ags** nn **Ans**

Fig. 1—Per cent of variance associated with general science and non-science achievement, contributed by twenty personality components when overlapping factors are kept constant. (*Contribution to non-science achievement by "self-sufficiency" is –.1 per cent; * * similar contribution to both criteria)

ferences were found between the correlations calculated between each of the twenty personality components and I.Q. and those calculated between each of the twenty personality scores and general science achievement scores. Likewise, no significant statistical differences are found between the multiple R's calculated for the aforegoing data.

On the basis of a multiple R calculated

by the Doolittle Method, ten personality components were found to be making positive contributions, ranging from two to nine per cent, to the variance associated with general science achievement scores.

The pattern of personality components, found to be offering positive contributions to the variance associated with general science achievement scores, differed from that pattern making positive contributions to the variance associated with I.Q. scores.

The use of the Wherry-Doolittle Test Selection Method, to determine a composite that would best predict general science achievement scores from the twenty personality components, proved to be impracticable.

A multiple R, calculated by the Doolittle Method, reveals, that when I.Q. is included as one of the variables, very little is added to the zero order coefficient of .75 representing the relationship found between intelligence quotients and achievement in general science.

When I.Q. *is not* included as a variable, the twenty personality components contribute approximately 21 per cent to the variance associated with scores in general science achievement. When I.Q. *is* included as one of the variables, the combined effect of the twenty personality components produces a contribution of only 6 per cent to the variance in general science scores.

When I.Q. is included as one of the variables it is possible to use the Wherry-Doolittle Test Selection Method. By means of this method a multiple R (corrected for chance errors) of .766 was calculated for the following regression equation:

$$\overline{X_1}=1.696X_{22}-.726X_3+.752X_{20}-87$$

where $\overline{X_1}$ represents the predicted general science achievement scores; "X_{22}" represents the calculated I.Q. score as determined by the Otis-Quick-Scoring Mental Ability Tests, Gamma, Form BM; "X_3" represents calculated score in "Health Adjustment" from the Bell Adjustment Inventory; "X_{20}" represents calculated scores in "Satisfying Work and Recreation" from the Mental Health Analysis, and "87" represents the constant which has to be subtracted from the sum.

The small contribution of .016, made by variables X_3 and X_{20} to the zero order coefficient of .75 between I.Q. scores and achievement in general science, does not warrant the use of a multiple regression equation to predict general science achievement scores from the use of these personality components.

SUMMARY OF FINDINGS NON-SCIENCE AND PERSONALITY

No substantial relationship was found to exist between the individual personality components and non-science achievement scores although seven of them were significant at the 1 per cent level of confidence.

Of the seven variables found to be statistically significant at the 1 per cent level of confidence, "Health Adjustment" (b) with the highest zero order coefficient of —.328 was contributed by the Bell Adjustment Inventory. The Bernreuter Personality Inventory contributed "Introversion-Extroversion" (g). The remaining five variables were contributed by the Mental Health Analysis and were: Feelings of Inadequacy (m), Behavioral Immaturity (k), Nervous Manifestations (o), Emotional Instability (l), and Satisfying Work and Recreation (s).

The data reveal several marked shifts in the level of confidence when the zero order coefficients of correlation between the twenty personality components and non-science achievement scores are compared with the zero order coefficients of correlation between the same components and general science achievement scores.

With the basis of reliability set at the 1 per cent level of confidence, the 103 students used as subjects for this part of the investigation were found, by means of calculated critical ratios, to come from the same population as the 157 students who were used as subjects for testing general science achievement.

By means of the "z" test of differences between "r's," no significant statistical differences were found to exist at even the 5 per cent level of confidence for the correlations calculated between the twenty personality components and non-science achievement and those calculated between the same components and general science achievement.

The calculation of a regression equation to predict achievement in non-science subjects from the combined use of the twenty personality components is not warranted since the zero order coefficient of correlation between the criterion and I.Q. (.458) and between the criterion and general science scores (.553) are both higher than the .446 calculated between the criterion and the twenty components by means of the Doolittle Method.

A comparison of the contributions made by the twenty personality components to the variance associated with non-science achievement scores and to the variance associated with general science achievement scores discloses not only a difference in the per cent of contribution but also in the pattern configuration.

The corrected multiple R of .446 calculated by the Doolittle Method, between the twenty personality components and non-science achievement, is raised to .611 when I.Q. scores are added as one of the variables.

The inclusion of I.Q. scores as one of the variables in the multiple R brings about changes in the amount of contribution previously made by the various components. Only one variable, "Social Participation" (r), is unaffected by the inclusion of the I.Q. scores in the multiple R.

By means of the Wherry-Doolittle Test Selection Method, the five components "Health Adjustment" (b), "Satisfying Work and Recreation" (s), "Social Adjustments" (c), "Introversion-Extroversion" (g) and "Feelings of Inadequacy" (m) produce a corrected maximum multiple R of .496 when I.Q. scores are not included as one of the variables.

When I.Q. scores are included as one of the variables, the Wherry-Doolittle Method selects six variables to produce a corrected maximum multiple R of .649, with a standard error calculated as .060, a standard error of estimate calculated at 2.19, and an Index of Forecasting Efficiency amounting to 23.07 per cent. The variables selected are: I.Q., Nervous Manifestations (o), Social Adjustment (c), Introversion-Extroversion (g), Satisfying Work and Recreation (s) and Health Adjustment (b).

When I.Q. scores are included as one of the variables in the multiple R, the Wherry-Doolittle Method selects the variable "Nervous Manifestations" (o) to replace the variable "Feelings of Inadequacy" (m) which was selected by the same method when I.Q. scores were not included among the variables.

The six variables, chosen by the Wherry-Doolittle Method, account for approximately 42 per cent of the variance associated with non-science achievement scores, and contribute to the following regression equation:

$$\overline{X}_1 = .119X_{22} + .096X_{16} + .205X_4 - .022X_8 + .214X_{20} - .120X_3 + 56$$

In the above equation $\overline{X}_1$ represents the predicted scores in non-science achievement, X_{22} represents I.Q. scores as determined by the Otis Quick-Scoring Mental Ability Tests, Gamma, BM; X_3 and X_4 represent, respectively Health Adjustment (b) and Social Adjustment (c) scores as calculated by the Bell Adjustment Inventory; X_8 represents "Introversion-Extroversion" (g) scores on the Bernreuter Personality Inventory; X_{16} and X_{20} represent, respectively, "Nervous Manifestations" (o) and "Satisfying Work and Recreation" (s) scores on the Mental Health Analysis; "56" represents the constant to be added.

THE RELATIONSHIP BETWEEN ACHIEVEMENT IN AN ADVANCED SCIENCE SUBJECT AND EACH OF THE VARIABLES CONSIDERED IN THIS STUDY

At the completion of their ninth-year of school, 39 of the subjects of this investigation elected, and completed, "Biology" as an advanced science subject for their tenth year. This part of the investigation will, therefore, be concerned with the relationships between achievement in biology and the numerous variables considered previously.

The score obtained by each of the 39 students on the Biology Regents Examination, taken at the end of their tenth year, was converted into a "T-score", and used as an index of achievement.

A detailed presentation of the interplay of forces contributed by the various personality components to the variance associated with general science, non-science, and biology achievement scores is shown by the composite diagram Figure 2 which combines the data from several of the tables used in the original study.

The following summary represents a condensation of the original findings.

SUMMARY OF FINDINGS PERSONALITY COMPONENTS AND BIOLOGY ACHIEVEMENT

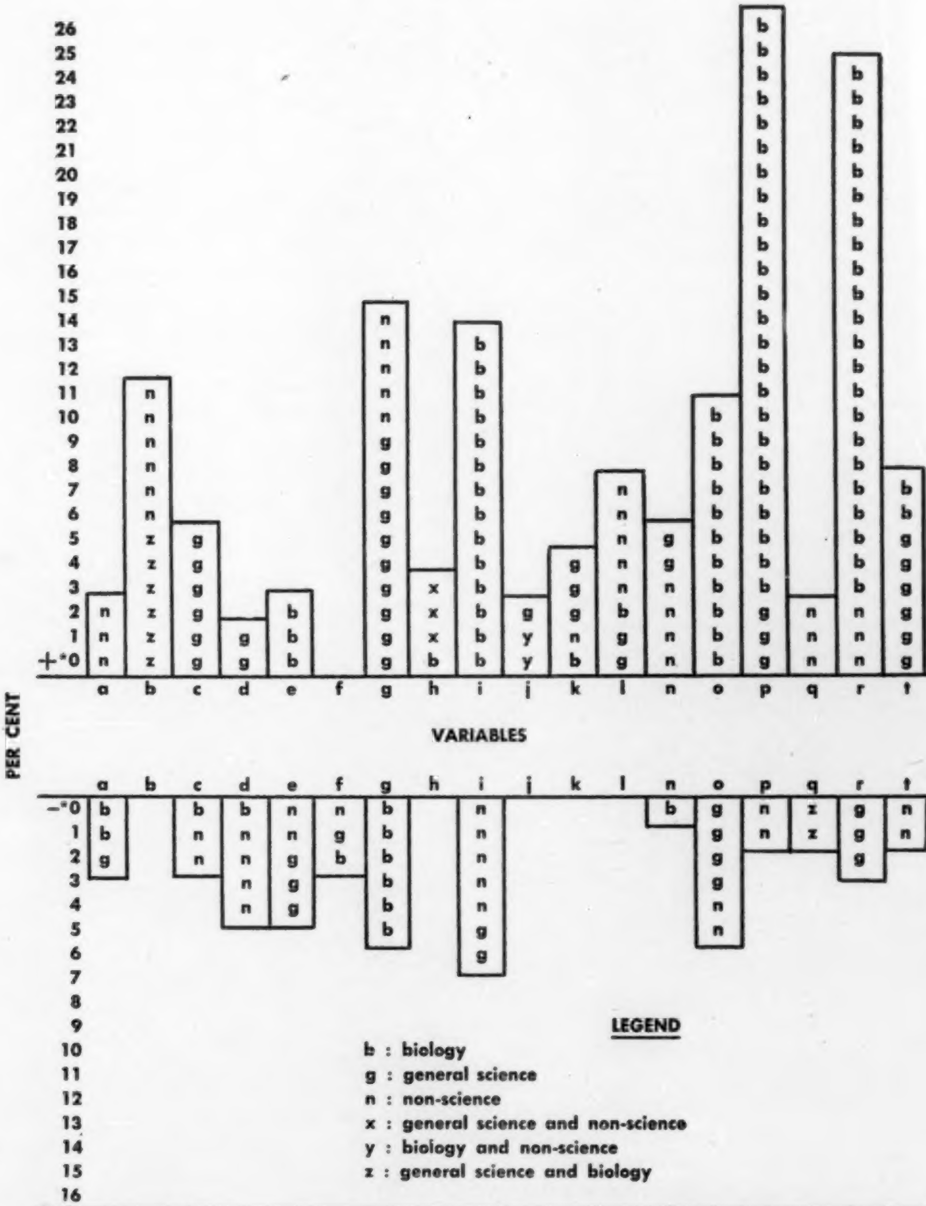
Only two variables, "Close Personal Relationships" (p) and "Social Participation" (r), are found to be significant at the 1 per cent level of confidence when correlated with biology achievement scores. The calculated "r's" were —.457 and —.415, respectively. The former value indicates that a substantial tendency exists for students who obtain high scores on the biology regents examination to lack a sense of security and well-being because of a lack of status with those who mean something to their welfare. The latter value (—.415) indicates a substantial tendency for high-scoring students to be in need of training in social etiquette and attitude building.

The contributions made by each of the twenty variables to the three criteria "achievement general science," "achievement non-science," and "achievement biology" vary not only in amount but also in confidence level of significance. On the basis of this comparison one may conclude that, on the basis of the zero-order coefficients of correlation, the pattern of personality components associated with achievement in biology differs from the patterns associated with general science and non-science achievement.

Using the techniques of the reliability of the difference between means of correlated groups, and the "z" difference between two "r's" having one variable in common, only two variables, "Feelings of Inadequacy" (m) and "Satisfying Work and Recreation" (s), were found to be non-representative of the same population. With the elimination of these two components, the pattern of personality components found to be significant at the 1 per cent level of confidence when correlated with biology achievement scores differs from the patterns found to be associated with general science achievement and non-science achievement.

A comparison of the per cent of contribution made by each of the twenty personality components, with and without the inclusion of I.Q. scores in multiple R's, showed differences in pattern configuration when general science, non-science, and biology achievement scores are used as the basis for comparison.

A best-fitting multiple R, calculated by the Wherry-Doolittle Test Selection Method, was found to include the variables "Close Personal Relationships" (p), "Adequate Outlook and Goals" (t), "Social Participation" (r), "Dominance-Submission" (h), "Social Adjustment" (c), and "Health Adjustment" (b). These six variables produce a maximum R amounting to .789 (corrected for chance errors) with biology achievement scores. The following additional data were calculated: standard error of .118; standard error of estimate of 6.134; Index of Forecasting



* Contribution is less than 1 per cent.

Fig. 2 — Per cent of contribution made by various personality components to general science, non-science and biology achievement scores when other variables are held constant.

Efficiency of 38.53 per cent. All of the aforegoing values are on the basis of T-scores.

The regression equation, based on the data used to calculate the maximum R referred to in the preceding paragraph is:

$$\overline{X}_1 = .490X_3 - .432X_4 + .305X_9 - .594X_{17} - .618X_{19} + .531X_{21} + 67.49$$

where $\overline{X}_1$ represents the predicted biology achievement scores; X_3 and X_4 represent, respectively, "Health Adjustment" and "Social Adjustment" scores as calculated from the Bell Adjustment Inventory; X_{17}, X_{19} and X_{21} represent respectively, "Close Personal Relationships," "Social Participation," and "Adequate Outlook and Goals" scores on the Mental Health Analysis; and X_9 represents the "Dominance-Submission" scores as calculated from the Bernreuter Personality Inventory. The value "67.49" represents the constant to be added to the T-score values calculated by the regression equation.

The six variables, combined, account for approximately 62 per cent of the variance associated with biology achievement scores.

When the regression equation is applied to the personality scores calculated for each of the subjects and the predicted T-scores then reconverted into raw scores, the following pertinent data are revealed: predicted mean of 78.35 as compared to actual mean of 79.73; predicted standard deviation of 17.48 as compared to the actual standard deviation of 13.12; coefficient of correlation between predicted scores and actual raw scores of .623 with a 4.845 "t" value; critical ratio of .6141 calculated by dividing the difference between the means of the raw scores by the standard error of the difference of the correlated means.

There were seventeen overestimations, nineteen underestimations, and three cases of perfect agreement between predicted scores and actual obtained scores. Theoretically, 26 cases should have been within 6.3 T-units (in either direction) of the predicted scores. Actually, 18 cases fell in the predicted category making our predictive efficiency only 69 per cent.

The results obtained are more reliable than those which could have been obtained by merely using I.Q. scores, or general science scores, as the basis for prediction.

REAFFIRMATION OF FINDINGS, TENTATIVE CONCLUSIONS, AND AREAS IN NEED OF FURTHER INVESTIGATION

This investigation was designed to ascertain whether a distinctive pattern of certain personality components is prevalent among high-school students who elect secondary-school science as a major subject, and is lacking among those who do not elect science as a major subject.

Various techniques were employed to determine the relationships existing among the general science, non-science and biology groups in endeavoring to ascertain personality patterns. Six of the patterns are shown in Tables VII and VIII.

The tentative conclusions which follow are presented with the realization that they apply merely to the students used as subjects of this investigation when tested with the specific measuring instruments used, at the end of their ninth-year of schooling. In addition, the conclusions are based on

TABLE VII

COMPARISON OF PERSONALITY COMPONENTS SIGNIFICANT AT 1 PER CENT LEVEL OF CONFIDENCE WHEN CORRELATED WITH GENERAL SCIENCE, NON-SCIENCE, AND BIOLOGY ACHIEVEMENT SCORES

General Science (N=157) Components	r	Non-Science (N=103) Components	r	Biology (N=39) Components	r
(m) Feelings inad.	.41	(b) Health adjust.	—.328	(p) Cl. pers. relat.	—.457
(t) Ad. otlk and gls.	.29	(m) Flgs. inad.	.297	(r) Social partic.	—.415
(s) Sat. wk. and rec.	.28	(o) Nerv. manif.	.294		
(b) Health adjust.	—.27	(l) Emot. instab.	.277		
(k) Behav. immat.	.24	(k) Behav. immat.	.278		
(n) Physical defects	.24	(s) Sat. wk. and rec.	.275		
(c) Social adjust.	—.22	(g) Introv.-extro.	—.258		
(d) Emot. adjust.	—.22				
(l) Emot. instab.	.22				

TABLE VIII

COMPARISON OF PERSONALITY COMPONENTS SELECTED BY WHERRY-DOOLITTLE TEST SELECTION METHOD TO PREDICT ACHIEVEMENT SCORES IN GENERAL SCIENCE, NON-SCIENCE AND BIOLOGY

General Science	Non-Science	Biology
Intelligence quotients	Intelligence quotients	(p) Close pers. relation.
(b) Health adjustment	(o) Nervous manifest.	(t) Adequate otlk. and goals
(s) Sat. wk. and recreat.	(c) Social adjustment	(r) Social participation
	(g) Introv.-extrov.	(h) Dominance-submission
	(a) Sat. wk. and recreat.	(c) Social adjustment
	(b) Health adjustment	(b) Health adjustment
$cR^2 = .5863$	$cR^2 = .4212$	$cR^2 = .6222$
$cR = .766$	$cR = .649$	$cR = .789$

the arbitrary assumptions that any findings below the 1 per cent level of confidence are unreliable for the purposes of this investigation. Finally, the conclusions are based on the statement that an "r" of .3 and an "E" of 4.6 usually represent the lowest level of validity coefficients found for useful predictive instruments in psychological and educational practice.

In presenting tentative conclusions based on the findings it is necessary to discuss vertical relationships between all of the components and each of the criteria, and the horizontal relationships between each of the components and all of the criteria.

THE PERSONALITY INVENTORIES

The value of the Bernreuter Personality Inventory as the sole measuring instrument for predicting any of the criteria is, to all intents and purposes, practically nil. In no instance did any part of this instrument reach a correlation of .3 with any one of the four criteria. On only two occasions does this instrument contribute correlations at the 1 per cent level of confidence: "Dominance-Submission" with "I.Q." ($r=.22$); "Introversion-Extroversion" with "Non-Science Achievement" ($r=-.258$). In addition, one notes from Table VIII that these two are the only two of the Bernreuter components selected by the Wherry-Doolittle Method for inclusion in maximum R's.

The value of the Bell Adjustment Inventory, for the purposes of this investigation, is found to be only slightly better than the Bernreuter Personality Inventory. "Home Adjustment" (a) does not correlate, at the 1 per cent level of confidence, with any of the four criteria. Five correlations are found to be significant at the 1 per cent level of confidence but in each instance the relationship is small. "Emotional Adjustment" (d) correlates to the extent of $-.22$ with general science achievement. "Social Adjustment" (c) is found to correlate to the extent of $-.28$ with "I.Q." and to the extent of $-.22$ with general science. "Health Adjustment" (b) is found to correlate to the extent of $-.27$ with general science achievement and $-.328$ with non-science achievement. Only the latter value is high enough to be used for predictive purposes. An inspection of Table VIII reveals that only "Health Adjustment" and "Social Adjustment" are selected by the Wherry-Doolittle Method for inclusion in maximum R's.

The Mental Health Analysis is found to contribute 21 correlations, at the 1 per cent level of confidence, with the various criteria. Of these, six correlations are high enough to be used for predictive purposes: "Feelings of Inadequacy" (m) when correlated with "I.Q." ($r=.38$; $E=7.5$), with general science achievement scores ($r=.41$; $E=8.8$), and with non-science achievement scores ($r=.297$; $E=4.6$); "Adequate Outlook and Goals" (t) when correlated with "I.Q." ($r=.31$; $E=4.9$); "Close Personal Relationships" (p) when correlated with biology achievement scores ($r=-.457$; $E=11.1$); and "Social Participation" (r) when correlated with biology achievement scores ($r=-.415$; $E=9.0$). An inspection of Table VIII discloses that the Wherry-Doolittle Method selects five

of the Mental Health Analysis components for inclusion in best-fitting multiple R's: Satisfying Work and Recreation, Nervous Manifestations, Close Personal Relationships, Adequate Outlook and Goals, and Social Participation.

Of the 28 correlations reported in the preceding paragraphs to be significant at the 1 per cent level of confidence, only two components are found in the correlations with biology achievement. These two, "Close Personal Relationships" and "Social Participation," are both contributed by the Mental Health Analysis.

On the basis of the aforegoing reports, one may infer that the Mental Health Analysis is superior to either the Bell Adjustment Inventory or the Bernreuter Personality Inventory, as a measuring instrument to ascertain the relationships between certain personality components and the criteria used in this investigation.

INTELLIGENCE QUOTIENTS AND PERSONALITY COMPONENTS

If one accepts Wechsler's statement that intelligence includes one's personality as a whole, then one of two premises must be accepted. Either the Otis Quick-Scoring Mental Ability Test is, or it is not, measuring the total personality. If one accepts the former premises then, on the basis of the findings in this study, the personality components used in this investigation are only accounting for approximately 15 per cent of the total personality. This latter assumption is based on the following findings. When all twenty of the personality components are used, by the Doolittle Method, to determine a multiple R with "I.Q.," a corrected coefficient of multiple determination amounting to .1427 is obtained. When the Wherry-Doolittle Method is employed, statistical difficulties are encountered which prevent the selection of certain components for a best-fitting maximum coefficient of multiple correlation. However, by trying various combinations of components, six personality components are found which produce a corrected coefficient of multiple determination amounting to .1676. Nothing is to be gained, however by calculating a regression equation using these six components since the single component "Feelings of Inadequacy" accounts for approximately 14 per cent of the variance associated with I.Q. scores.

Furthermore, if the Otis test is both a reliable and valid measurement instrument, and is measuring aspects of the personality, it should produce consistent results. This is not borne out by the evidence presented in this study. When "I.Q." scores are *not* included as one of the variables in a multiple R with general science achievement, the twenty personality components are found to contribute 21.21 per cent to the variance associated with general science achievement. When "I.Q." scores *are* included as one of the variables, the contributions of the personality components are reduced to 6.42 per cent. However, when "I.Q." scores are *not* included as one of the variables in a multiple R with non-science achievement, the personality components contribute 32.57 per cent to the variance; when the scores *are* included, the personality component contributions are only reduced to 28.67 per cent. A similar situation is confronted when one considers the effect of "I.Q." scores on the contributions made by the personality components to achievement in biology. When "I.Q." scores are *not* included, the components contribute 84.10 per cent to the variance associated with biology achievement scores; when the scores *are* included, the contributions are only reduced to 81.64 per cent. In addition, the evidence reveals that the inclusion of "I.Q." scores in a multiple R produces a change not only in the amount of contribution made by each personality component, but also a change in the direction of the contribution, depending on the criterion being used.

One is therefore left with the second premise and must conclude that the Otis Quick-Scoring Mental Ability Test *is not* measuring the total personality but, on the basis of the evidence presented, is measurnig "something" which it has in common

with the personality components used in this investigation.

ACHIEVEMENT SCORES AND PERSONALITY PATTERNS

The relationships existing between the various personality components and achievement in general science, non-science, and biology have already been discussed. In addition, a comparison of zero order coefficients of correlation, multiple R's calculated by the Doolittle Method, regression equations calculated by the Wherry-Doolittle Method, and by the use of the "z" test of differences between "r's" having one variable in common, have revealed differences in the pattern configuration of the personality components. On the basis of the aforegoing evidence one must conclude that the personality pattern associated with those students who elect biology as an advanced secondary-school science differs from the personality pattern associated with those students who do not elect an advanced science.

PRACTICAL ASPECTS

The best-fitting personality pattern found to be associated with biology achievement scores include the following components: Close Personal Relationships, Adequate Outlook and Goals, Social Participation, Dominance-Submission, Social Adjustment, and Health Adjustment.

Although the variations reported for the small number of subjects used in this part of the investigation are too great to permit the use of the calculated regression equation to predict individual scores in biology achievement, nevertheless, the $_{C}R^2$ of .62 and $_{C}R$ of .789 calculated between the personality components above and biology achievement, and the "r" of .623 obtained between predicted and actual scores are more reliable than those which could be obtained by merely using the correlation of .42 calculated between "I.Q." and biology, or the correlation of .64 calculated between general science and biology. In addition, the supporting statistical data reported throughout the study are significantly reliable and indicate that closer agreement between prediction and actuality might possibly be obtained by more accurate and refined techniques.

AREAS FOR FURTHER STUDY

It is the opinion of this investigator that the evidence disclosed by this research problem is of sufficient high reliability to justify some other investigator to conduct another study to test the validity of the findings. It is suggested, however, that the following modifications of technique be employed.

The future investigator should start off with the use of those variables selected for the biology achievement regression equation.

The selected tests should be administered to two matched groups of relatively large size within a single population.

Tests should be left in raw score form since the conversion into T-scores of the large number of scores involved only increases the amount of possible errors.

The techniques suggested by Mosier [6:5-11], i.e. "cross-validation," "validity-generalization," "validity-extensions," and "replication" should be employed to test the validity of the findings. The method of cross-validation, where the weights are determined on one sample and their effectiveness tested on a second, similarly drawn sample, could not be employed by the present investigator since the 39 students investigated represented the total number of students within the original population who elected an advanced science subject. This number is too small to be divided into two groups.

On the basis of the statistical difficulties encountered in the present investigation, there is a need for personality inventories and similar measuring instruments so constructed that high scores on each would be indicative of favorable responses.

On the basis of the findings revealed in this study, there is a definite need for the

re-defining and re-refining of the aspects of the total personality.

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SCIENTIFIC THINKING: A BASIS OF ORGANIZATION FOR PHYSICAL SCIENCE LABORATORY PROGRAMS IN COLLEGE GENERAL EDUCATION *

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1. INTRODUCTION

EMPHASIZED here are a particular historical and a particular contemporary problem-solving treatment of the physical science laboratory period for college general education. These two treatments were developed in parallel by the writer for an experimental comparative study with students at the University of Minnesota during Fall, 1950 and Winter, 1951. In another paper,[1] the writer has paid special attention to the experimental design, procedures, and statistical analyses of the study itself. We are, therefore, free here to concentrate in some detail upon the organization and materials of the two contrasted scientific problem-solving laboratory treatments themselves.

2. THE ISSUES

Primarily we are concerned with the effective use of the physical science laboratory period in college general education. The individual laboratory in practice is in decline as against the lecture demonstration. For example, there is no regular laboratory period in ninth grade general science courses; newer fused biology or physical science courses in other high school grades have decreased amounts of individual laboratory work; [2, 3] a large majority of the outstanding colleges featuring college physical science for general education, as the University of Chicago or the University of Minnesota General College, use lecture demonstration in place of the individual laboratory.[4]

Reasons for this decline are:

(a) Pressure for reducing costs in an expanding science enrollment.

(b) The economy of time in the use of demonstrations.

(c) Dissatisfaction with the "cook book" routine of the usual individual laboratory practice.

(d) The conception that laboratories in high school and college have primarily technical education rather than unique general education values and functions.

(e) Disappointment in comparative results shown by individual lab methods in various experimental investigations. The idea would be that in order to justify the extra time and expense involved, the individual laboratory as a method must show significantly better results than other methods.

There are serious weaknesses underlying the above experimental studies, practices, and reasoning away from the individual laboratory period. First of all, they are based upon ideas of laboratory *versus* demonstration as against determining the best functions or uses of each, and exploiting each for its own particular advantages or uniquenesses. Second, there is too much blanket use of the idea of individual labs and demonstrations. Individual labs vary widely in character and possibilities as do demonstrations. Third, in the research of the issue there is over-emphasis on comparison of *status quo* practices rather than on comparisons involving possibly better methods. For example, there are some conclusions and recommendations for reducing laboratory time, or substituting

* Based on Doctoral Study completed at the University of Minnesota.

[1] Perlman, James S., "An Historical vs. Contemporary Problem Solving Use of the College Physical Science Laboratory Period for General Education," *Journal of Experimental Education*, March, 1953.

[2] N.S.S.E., 31st Yearbook Part I, 1932.

[3] N.S.S.E., 46th Yearbook Part I, 1947.

[4] McGrath, E. J. (Editor), *Science in General Education*, Dubuque, Iowa: William C. Brown Company, 1949.

demonstrations, recitations or extra reading for it on the basis of the traditional, illustrative, "cook book" or deductive uses of the laboratory as against inductive or problem-solving possibilities. Fourth, results have been based generally upon measurement of outcomes of laboratory or demonstration work in terms primarily of facts and principles without consideration of acquisition of instrumental skills, of problem-solving abilities, or of scientific attitudes. Thus, from a broad viewpoint, most of the research upon which practice and reasoning on this issue are based, would hang limp even without such very serious statistical and experimental deficiencies as fallacious sampling, weighting of variables for the equating of groups, lack of provision for reliability of tests, or skimpy descriptions of procedures.

The uniqueness of the science laboratory period for general education purposes would seem to lie in the opportunities it provides for first hand material, first hand evidence, and first hand experience in a larger picture of problem-solving. It is for this reason that we have been interested again in posing the effective use of the laboratory period, but on a new, a problem-solving basis. Such a basis would be one in which the laboratory period is devoted to conscious scientific problem-solving aims, procedures, materials, and tests in order to achieve scientific problem-solving approaches, attitudes and abilities as outcomes.

For such outcomes, would historical or contemporary treatments be more effective? Assumptions in the development of historical problem-solving approaches would be that various case-histories in science properly chosen would enable (a) problem-solving generalizations for transfer to modern life, (b) insights on modern life through historical perspectives as well as through historical similarities. Assumptions in the development of contemporary problem-solving treatments of the laboratory would be that contemporary problems (a) afford problem-solving generalizations through accumulative direct experience for further application, (b) enable insights on modern life through direct familiarity with it, and (c) facilitate transfer by enabling teaching for transfer under conditions natural and close to contemporary life. The issue as to an historical or contemporary approach essentially is the question of whether we can better develop problem-solving abilities, attitudes, and resourcefulness for contemporary living by appreciatively and realistically duplicating and analyzing in the laboratory, critical experiments of outstanding scientists of the past, or by working directly and inductively with students in their own immediate contemporary problems of science.

3. THE PARALLEL HISTORICAL AND CONTEMPORARY LABORATORY TREATMENTS

In general, the individual laboratory courses of the physical science class mentioned above consisted of fourteen contemporary problems parallel to fourteen case histories. Although there had been a number of historical methods from which to choose, we selected the Conant case-history method [5] and its emphasis upon the "strategy and tactics of science" as the most promising for our historical problem-solving purposes. The general class procedures took the following form:

(1) The particular historical problem was posed and defined by the instructor according to the status and the dynamics of the problem at the time.

(2) The "given" and the leads in the situation were analyzed.

(3) The hypothesis of the particular scientific thinker as against other hypotheses was emphasized along with the basis for the particular selection.

(4) The class "re-created" and performed the critical experiment generally designed for hypothesis verification or rejection. The originality and resourcefulness of the experiment were em-

[5] Conant, *On Understanding Science*, Yale University Press, 1947; Conant, *The Growth of the Experimental Sciences*, Harvard University Press, 1949; Roller, *Rise and Decline of Caloric Theory*, Harvard University Press, 1950; Nash, *The Atomic-Molecular Theory*, Harvard University Press, 1950.

phasized. The data were systematized, compared, and interpreted.

(5) The critical nature of the experiment, its implications and applications, at the time, were discussed.

(6) The class analyzed, evaluated, and summarized all the above in terms of the problem-solving involved.

The contemporary problem-solving method was essentially one in which class arguments or discussions were initiated through such devices as newspaper clippings or challenging statements and questions in order to be scientifically resolved and evaluated with as much instructor-class planning as possible, and with individual experimentation. That is, the class activities generally took the following pattern:

(1) A class discussion or argument was initiated from pertinent newspaper clippings, from challenging remarks, questions, quotations, or the like.

(2) After a reasonable time, the problem involved was pointedly defined and clarified.

(3) Various suggestions for solution or hypotheses of class members were considered.

(4) A "best" hypothesis was selected and analyzed.

(5) An experiment was outlined and carried out with as much class planning as possible.

(6) Data were systematized, compared, and evaluated.

(7) Conclusions with necessary qualifications were formed.

(8) Implications and applications were considered.

(9) The scientific problem-solving in all the above was discussed and analyzed.

As in the historical method, problem-solving generalizations, wherever possible, were formed.

Thus, in both the historical and the contemporary methods, the laboratory materials and methods were used in a larger picture of problem-solving and thinking. There was a pointed emphasis upon scientific methodology and approach to problems rather than upon the usual deductive, illustrative, or routine apparatus manipulation. Materials and experimentation were used as evidence and as a basis for conclusions in the general process of problem-solving. Thus, the actual use of the laboratory materials and equipment was preceded by the posing, clarification, and discussion of the tentative solutions of the problem involved, as well as followed by discussion and evaluation of the conclusion-formation, and the problem-solving involved.

The same problem-solving conceptual outcomes were set up as objectives for both treatments and developed in class as generalizations. Since, in a sense, these conceptual outcomes represent the real subject matter and basis of evaluation of the problem-solving laboratory courses, we list them below as general problem-solving "high points," which are grouped according to whether they involve considerations of critical discrimination, of systemization and generalization, or of verification.

Physical Science I–II Laboratory

General Problem-Solving "High Points"

A. Considerations of Critical Discrimination

1. We can not always trust our senses and impressions.
2. Man is as powerful in understanding and controlling his environment as the tools he fashions for the purpose.
3. There are both similarities and differences in things.
   (a) Analogies based on similarities often afford fruitful leads in solving problems.
   (b) Dangers of analogies lie in not recognizing differences.
   (c) It is important to understand things in terms of opposites.
   (d) Look for the exceptions to things.
4. Definitions also based on similarity and difference afford an excellent tool for establishing a basis for problem-solving.
5. The use of authorities involve careful considerations.
   (a) Authority is relative to given fields.
   (b) In the same field, equally good authorities do not always agree.
   (c) Individual thought with first hand evidence in addition to use of authority is necessary for progress.
   (d) Best basis for judgment of value of a source is the training and purpose of the author.
6. Variation, change, and motion are common to all things.
7. Look for the basic elements and factors in a problem situation.
8. Know the differences among fact, assumption, and definition.

B. Considerations of Systematization and Genalization.

9. Systematization is based on similarities.
10. Graphs and charts afford a valuable tool for the organization and interpretation of data.
11. Shrewd, careful, tentative guessing can be very fruitful and productive in problem-solving.
12. Generalization, however, that is either too hasty or too cautious blocks progress.
13. Technology and medicine reflect the tremendous tool of cause and effect relationships on a natural rather than on a supernatural basis.
14. Other things being the same, the simpler the explanation, the more the probability of success.

C. Considerations of Verification

15. Everyone is entitled to his opinion, but not all opinions can stand up equally under the facts.
16. It is more important to be able to anticipate and to detect errors in problem-solving than to expect perfect solutions.
17. Many leads and hypotheses often have to be tested before the best solution is found.
18. Conclusions and statements, therefore, should be qualified according to the limits of the particular problem, conditions, and evidence.
19. Since facts are never completely all in, certainty can merely be approached, not arrived at. Conclusions, therefore, are merely the best evidence of the time, and require open-mindedness for further verification, improvement, or change.
20. In some cases there is more than one correct answer to a problem due to two answers being different aspects of the same thing, or due to need for additional knowledge.
21. The larger the number of cases as evidence, the greater the possibility of truth.
22. Every statement, opinion, or idea rest upon some assumption, and is no more solid than its assumption.
23. The hypothesis, the theory, the law, and the axiom indicate degrees of certainty.

Another similarity of treatment between the historical and the contemporary methods was in the one hour orientation lecture of the first double laboratory period after the pre-test. In this orientation, the writer emphasized the universality of problem-solving in personal and social affairs, and the need for a scientific problem-solving approach. While final answers to problems were presented as not always possible, a scientific approach, that is, an open-minded, systematic and critical approach based on evidence was emphasized as possible. To the historical group, the writer then read the following brief passage, and asked whether they, the students, were any better governed by facts and evidence than the group in the following story:

> In the year of our Lord 1432, there arose a grievous quarrel among the brethren over the number of teeth in the mouth of a horse. For thirteen days the disputation raged without ceasing. All the ancient books and chronicles were fetched out, and wonderful and ponderous erudition, such as was never heard of in this region, was made manifest. At the beginning of the 14th day, a youthful friar of goodly bearing asked his learned superiors for permission to add a word, and straightway, to the wonderment of the disputants whose deep wisdom he sore vexed, he beseeched them to unbend in a manner coarse and unheard of, and to look in the open mouth of a horse and find answer to their questionings. At this, their dignity being grievously hurt, they waxed exceedingly wroth; and joining in a mighty uproar, they flew upon him and smote him hip and thigh, and cast him out forthwith. For, said they, surely Satan hath tempted this bold neophyte to declare unholy and unheard of ways of finding truth contrary to all the teachings of the fathers. After many days more of grievious strife, the dove of peace sat on the assembly, and they as one man, declaring the problem to be an everlasting mystery because of a grievous dearth of historical and theological evidence thereof, so ordered the same writ down.[6]

To the contemporary groups, the instructor read a recent newspaper report of a widow who insisted that a "glowing cross" on the wall of her home was a "miraculous" sign from her dead husband—until three newsmen placed a piece of paper over a mirror edge.

The instructor then described what he considered four general approaches to problems. These were approaches that essentially were characterized by (1) emotion, superstition, authoritarianism; (2) trial and error, which involved no initial plan or systematization but was sometimes necessary for leads; (3) common sense, based on appearances and often on false analogies; (4) scientific problem-solving, essentially openminded, systematic, critical,

[6] Davis and Barnes, Editors, *Readings in Sociology*, D. C. Heath and Company, 1927, pp. 125–126.

TABLE I

SCHEDULE OF PROBLEMS OF HISTORICAL AND CONTEMPORARY GROUPS DURING FALL, 1950

Week of	Topic	Historical Groups	Contemporary Groups
Oct. 23	"Spontaneous" processes and natural causes	Case 1. Lightning and the Wimshurst Machine. Problem: How Did Man Create Lightning?	Problem 1: What Causes Powder Plant, Flour Mill, or Coal Mine Explosions?
Oct. 30	Optical instruments	Case 2. We Can Not Trust Appearances. (Ptolemy, Copernicus and Galileo's Telescope.) Problem: Does the Sun Revolve Around the Earth or the Earth Around the Sun?	Problem 2: Just How Do Your Eyes Enable You to See? What Optical Defects Develop and How Are They Corrected? (The Eye as an Optical Instrument.)
Nov. 6	Uniformly accelerated motion	Case 3. Galileo's "Falling Bodies." Problem: Do Light Objects Fall as Fast as Heavy Ones?	Problem 3: How Much Further Does a Car go When Applying Brakes at 60 M.P.H. Than at 30 M.P.H.?
Nov. 13	Velocity vectors and gravity	Case 4. From Galileo's Gravity to Newton's Gravitation. Problem: To what Extent Does the Moon "Fall" to the Earth?	Problem 4: Should a Marksman Aim *At* or *Below* a Freely Falling Target as it Begins to Fall?
Nov. 20	Air pressure and its measurement	Case 5. Torricelli and the Barometer. Problem: Does Nature Abhor a Vacuum?	Problem 5: Why Are the Ears Affected When Ascending or Descending in a Plane? To What Extent Do We Live Under an Ocean of Air?
Nov. 27	Air pressure effects	Case 6. Boyle's "Spring of the Air." Problem: Does Nature Abhor a Vacuum? (continued)	Problem 6: Why Are the Ears Affected When Ascending or Descending in a Plane? What are the Effects Upon Walls or Ear Membranes from Changes in Pressure?
Dec. 4	Buoyancy	Case 7. Archimedes' Principle—Bouyancy and Specific Gravity. Problem: How Could Archimedes Have Detected the Purity of Gold in a Crown Without Damaging the Crown?	Problem 7: Does the Platform Balance Show You Your True Weight?
Jan. 15	Human conduction of electricity	Case 8. Galvanic "Animal Electricity" and the Voltaic Cell. Problem: Is There "Animal Electricity?"	Problem 8: Why is it Dangerous to Have Fixtures or Appliances Near a Bath Tub?
Jan. 22	Electro-magnetic conduction	Case 9. Faraday and Electromagnetic Induction. Problem: How Could Magnets Give Rise to Electric Currents?	Problem 9: How Does Western Union Send Its Messages?
Jan. 29	Electrolysis	Case 10. Dalton's Atomic Theory and Electrolysis of Water. Problem: How Did We Come to Identify Water as H_2O?	Problem 10: (a) How May Silverware Be Cleaned Most Efficiently? (b) How Does Industry Separate Pure Copper from Ore?

TABLE I—(*Continued*)

Feb. 5	Reduction	Case 11. Priestley's Discovery of Oxygen (Dephlogisticated Air). Problem: How Was it Possible for Some Air to Intensify Combustion While Other Air Put Out a Flame?	Problem 11: (a) Why is Carbon Monoxide a Killer and How Can it be Defeated? (b) How Could a Chemical Change Black Skin to White?
Feb. 12	Oxidation	Case 12. Lavoisier's Oxidation and the Overthrow of the Phlogiston Theory. Problem: How Could a Calx (Mercuric Oxide) Weigh More than the Metal from Which it was Formed?	Problem 12: What is Fire and How is it Best Fought with Water and Chemicals?
Feb. 19	Titration	Case 13. Development of the Chemical Equation as a Powerful Tool and Ostwald's Titration. Problem: How Was It Possible to Predict the Emergence of Table Salt from Two Poisons?	Problem 13: (a) What Does Baking Soda Do When Taken for "Heartburn?" (b) What is Dark Discoloration of an Aluminum Pot and How Can We Most Easily Bring Back the Shine?
Feb. 26	Synthetic or commercial chemicals	Case 14. Berzelius' Catalysis and Man-Made Oil of Wintergreen. Problem: How Has Man Copied or Improved Upon Nature?	Problem 14: (a) How Does Soap Clean? (b) How Do Different Commercial Water Softeners Compare?

and based on evidence. The orientation lecture was then completed with the explanations that the laboratory periods of the course would be devoted to experience in the last approach.

In respect to differentiation between the historical and contemporary methods, it was a differentiation as we have previously expressed it, as to whether problem-solving abilities, for contemporary living, can be more effectively developed by the class appreciatively and realistically duplicating and analyzing the accumulative problem-solving of outstanding scientists of the past, or by the class working directly with immediate problems of their own.

The former treatment involved historically centered problems and laboratory equipment; the contemporary treatment involved contemporarily focused problems and equipment. Perhaps we can best illustrate this by presenting here in Table I the actual schedule of problems of the historical and contemporary student groups followed during Fall, 1950 and Winter, 1951.

For more detail, we present further from a log of actual class procedures and activities, two parallel sample problems each in physics and in chemistry for the historical and contemporary methods:

HISTORICAL GROUPS, OCTOBER 24, 1950

Case 1. Orientation Topic: "Spontaneous" Processes and Natural Causes.

Problem: How Did Man Create Lightning?

1. The instructor introduced the problem by calling attention to the "awe-full" character of lightning as a "spontaneous" process in its role in mythology.
2. This lead to consideration of
   - (a) Ancient man's experiences with lightning and his explanation by supernatural causes.
   - (b) The observed rubbing phenomena of Gilbert.
     The class individually duplicated his experiences with amber or vulcanite rods and fur, and with glass rods and silk.
   - (c) The special electrophorus of Von Guericke. The class duplicated his discoveries of electrical repulsion as well as charge by induction.
   - (d) The Leyden jar of Nollet.

(e) The Wimshurst electrostatic machine.
The students individually experienced charging and discharging Leyden jars and Wimshurst machines.

3. On the basis of the above, the following activities also took place:
   (a) The thinking was analyzed by the class and summarized in the lab notebooks.
   (b) Examples of further implications and applications, as lightning rods and condensers, were asked of the class, discussed and recorded.
   (c) The vantage point of modern man with such accumulative evidence for natural causes as the above, as against ancient man and his supernatural explanations, became a "high point."
   (d) Likewise, the probability of future man having accumulative evidence for phenomena that we now do not have, and of pushing back other superstitions, supernaturalisms or mysticisms of our time, was also made as a "high point" by the instructor.

CONTEMPORARY GROUPS, OCTOBER 25, 1950

Problem: What Causes Powder Plant, Flour Mill, or Coal Mine Explosions?

1. The instructor introduced the problem, pointing out that at the Dupont Powder Plant at Rosemount during the last war, each employee had issued to him a pair of "safety" shoes. Powder plant, flour mills, and coal mine explosions of the past were cited.
2. Various considerations of dust, gas collection, electrostatic or other sparks, kindling temperature, etc. were analyzed as factors in the explosion situations.
3. As evidence, the instructor created a miniature dust explosion with the appropriate equipment of cornstarch in a can, with provision for gas accumulation, for a spark, etc. The explosion took the form of the cover being blown off. Because of the danger involved, this by necessity was an instructor demonstration.
4. To clarify concepts of kindling temperature, the students were asked to resolve an argument as to whether or not a paper container with water in it would burn if placed over a flame. This was resolved by the students actually trying it. The majority of the students had expected the paper cups to burn, and were consequently quite surprised to find that this did not happen.
5. Conclusions, qualifications, and assumptions were made in regard to the original problem question.
6. The class and instructor evaluated the problem-solving involved in terms of the problem clarification, leads, hypotheses, and verification as it actually occurred in class.
7. A particular high point involved, for purposes of safety, health and happiness, the recognition of the necessity for approaching and understanding phenomena in terms of natural causes.
8. As part of their summarizing lab report, the students indicated examples of further implication or application to the above special high point of natural causes, as, for example, the spontaneous combustion of dirty or oily rags in an unventilated place.

HISTORICAL GROUPS, OCTOBER 30, 1950

Case 2. We Can Not Trust Appearances. Ptolemy, Copernicus and Galileo's Telescope.

Problem: Does the Sun Revolve Around the Earth or the Earth Around the Sun?

Historical Background and Leads of Problem During Galileo's Time:

1. The deadlock between the Ptolemaic and the Copernican Theories was emphasized: each theory alone could explain about equally well, observed astronomical phenomena, as for example, Venus' apparent change of direction.
2. Discovery of the first practical telescope in Holland in 1608 by Lippershey [7] was described.

Galileo's Use of His Own Improved Telescope as Empirical Evidence for the Copernican Theory: The problem-solving centered around Galileo's construction and use of the telescope, and his significant discovery of Venus' phases and Jupiter's moons.

1. The class constructed Galilean telescopes (modern opera glasses) by use of concave and convex lenses after first determining the focal lengths of the lenses.
2. After adjustment, the distance between the two lenses was checked against the difference between the focal lengths of the lenses. (These should be about equal.)
3. The magnifying power was determined by superimposing a magnified image of a paper scale on a wall upon the unmagnified scale.
4. The various values of magnification within the class was compared to each other as well as to the reported magnification of *30* obtained by Galileo. Differences in magnification of the individual telescopes were analyzed in terms of differences of construction as for example, focal lengths, distances, etc.
5. Approximate scale drawings were made of image formation.

Other Developments or Applications: The astronomical telescope and the microscope.

Problem-Solving High Points especially pertinent in this case:

1. We cannot judge by appearances (apparent motion of sun around earth).
2. Man is as powerful as the instruments and tools he develops for the extension of his senses and knowledge.

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[7] *Encyclopedia Brittannica*, Eleventh Edition, 1911, Vol. 26, pp. 558–559.

3. Empirical evidence is indispensable for scientific problem-solving.

CONTEMPORARY GROUPS, NOVEMBER 2, 1950

Problem 2: Just How Do Your Eyes Enable You to See? What Optical Defects Develop and How Are They Corrected? After initial class discussion or argument in which the problem was defined and clarified, and various ideas of the class members were considered, apparatus of the following nature was brought in as evidence:

1. A large sized eye-model with provisions for defects of nearsightedness, farsightedness, etc.
2. Concave and convex lenses of various dioptric strengths.
3. Lamp box as object.

This apparatus was then used as evidence:

1. To establish an analogy with an actual normal eye.
2. To permit students individually to check the dioptric strengths of the above lenses by determining the focal lengths, or to determine the dioptric strength of lenses in "specs" that they themselves were wearing.
3. To analogously create eye defects as farsightedness, nearsightedness, astigmatism, cataract, in order to make eye corrections and to analyze what is involved.
4. To permit students to test their own glasses and to determine character and extent of their own eye deficiencies by "neutralization" with lenses of opposite sign.
   Further application and inference was comparison of the eye to a moving picture camera. The work terminated, of course, with the usual analysis of the problem-solving involved, and consideration of problem-solving high points.

HISTORICAL GROUPS, FEBRUARY 6, 1951

Case 11. Priestley's Discovery of Oxygen (Dephlogisticated Air)

Problem: How Was It Possible For Some Air To Intensify Combustion While Other Air Put Out a Flame?

Historical Background:

1. Conception of ancients: air as one of the four basic elements or essences.
2. Later Medieval Alchemists and Metal Makers:
   (a) Air as weightless "spirits, vapours, odors" given off when substances are burned; object burned → elemental substances + "spirits."
   (b) Solids classified as:
      1. metals,
      2. "earths" or "calces" (oxides of today),
      3. "combustible principles" as charcoal or sulfur, e.g., An Earth (or Calx) + Charcoal → A Metal, or A Metal + Heat → An Earth (or Calx).
3. Phlogiston Theory as a Step forward:
   (a) Phlogiston: a *metalizing principle* or essence.
   Calx + Phlogiston (From Charcoal) → Metal
   Metal Heated in Air → Calx + Phlogiston (To the Air).
   (b) No need for separate "combustible principles" of charcoal, sulfur, etc. Rather, these substances were ones that contained the same, single combustible principle of phlogiston.
   (c) Assumptions and inferences of phlogiston theory:
      1. *Assumption:* calces simpler substances than metal.
      2. *Inference:* therefore, "something" must be added to make calces, or pure earths, into metals.
      3. *Observation and assumption:* metals formed are much more alike than diversified calces from which they supposedly are formed.
      4. *Inference:* therefore, the "something" added must be the same thing in all cases: Phlogiston.
   (d) Contradiction to assumption (1) above of the phlogiston theory: reports that a calx weighed more than the metal from which it was formed.
4. Experimentation revealing a type of "air" that wouldn't permit burning.
   (a) Van Helmont observed that not all air was the same: "air" of burned charcoal was unable to support combustion.
   (b) Black (1754) observed that if acid was poured on chalk, the bubbles given off did not support combustion. He called these bubbles Fixed Air.
5. Priestley's highly significant discovery of a "dephlogisticated air" that was 'five or six times better than common air for respiration and combustion.' [8]
   (a) Details of discovery:
      1. He heated red oxide of mercury properly enclosed.
      2. He found that the "air" collected 'was like common air' but that it caused the applied candle to burn much more brightly.
   (b) Interpretation of his finding through Phlogiston Theory:
      1. Calx (Red Oxide of Mercury) + Phlogiston (from common air) → Mercury + Dephlogisticated Air.
      2. In other words, the new element, oxygen, which he had discovered was not to him a new element, but merely common air with some phlogiston removed.

Class Experimental Activity: The class duplicated the experiences of Van Helmont, Black,

[8] Conant, *On Understanding Science*, 1947, p. 85.

and Priestley, described above, in each case collecting the gas product and testing it with a flame. (The class was warned, however, against the danger of searching for leaks or of testing gases under non-laboratory conditions.)

Examples of Problem-Solving High Points of This Case:

1. The Phlogiston Theory was a step forward from previous theories in affording a simpler explanation, e.g., a single phlogiston essence instead of many separate "combustion principles" of sulfur, etc.
2. Yet this Theory, in turn, became an encumbrance to progress when, because of its prevalence, Priestley insisted upon the explanations of his findings in terms of this Theory. This prevented his recognition that he had discovered a most significant new element, oxygen.
3. Or, every man rests upon the shoulders of those who have preceded him, but may, at times, be handicapped by the conditioning that results from that fact.
4. Even outstanding men may slip by ignoring facts contradictory to their postulations or beliefs: Priestley ignored the issue involved in the mercuric "calx" weighing more than the mercury from which it was formed.
5. A theory is no stronger than its weakest assumption.

Contemporary Groups, February 8, 1951

Problem 11-a: Why Is Carbon Monoxide A Killer and How Can It Be Defeated?

Posing of Problem: Through news clipping, "Car May Be a Death Trap."

Problem Clarification and Exploration:

1. The dangers and fatalities of carbon monoxide poisoning to motorists, particularly during the winter were discussed and analyzed.
2. Special emphasis was given to running motors in closed or even partially closed garages or in parked, completely closed cars; to the chemical processes involved in the poisoning, and to the precautions to be taken.

Class Experimental Activity: Obviously, in this case, experimental verification must be analogous in character.

1. Carbon dioxide was collected by combining calcium carbonate and dilute HCl. The chemical process involved was determined.
2. The carbon dioxide was used to snuff out a candle flame.
3. The similarity in the analogy was drawn between the carbon dioxide depriving the candle flame of oxygen and thus snuffing it out, and the carbon monoxide, inhaled in the lungs, depriving the red blood cells of their oxygen and thus causing death.
   The differences involved in the analogy, however, are also pointed out as a matter of the carbon dioxide by its *physical presence* not permitting enough oxygen to approach the candle for combustion as against the carbon monoxide which *chemically combines* with the hemoglobin in the red blood cells, preventing oxygen intake by the hemoglobin.

Example of Problem Solving High Points: Where direct evidence in problem-solving is not possible, analogies based on similarities may afford valuable insights and evidence if points of dissimilarity are given full consideration.

Problem 11-b: How Could a "Chemical Change Black Skin to White"?

Posing of Problem: Attention was called by the instructor to a lengthy news clipping with the above caption based on an article by Walter White, former head of the National Association for the Advancement of Colored People.

Exploration and Clarification of Problem:

1. The specific scientific factors and social implications as they applied to the specific Negro tannery workers in the article were discussed and analyzed.
2. Since racial discrimination shows itself primarily on the basis of skin color, the class problem was narrowed down to consideration of racial discrimination and chemistry of the skin.
3. Negro-white skin differences became apparent as a matter primarily of variation in the amount of dark pigment, melanin, coloring the skin. This is in contrast to a social background in the U. S. in which the Negro as a race has long been kept from more than second or third class citizenship, and to an explosive international situation in which past unhealthy Occidental-Oriental race relations have played no small part.

Class Experimental Activity: Since the removal of melanin by monobenzyl ether of hydroquinone is both unfeasible and dangerous in a classroom, the students, by analogy, removed fruit and other stains from cloth with hydrogen peroxide.

Example of Problem-Solving High Points in This Case: The open-minded, systematic and critical approaches to problems, struggled for and practised in the physical sciences have afforded the tremendous technological and industrial progress of our present world civilization; the lack of corresponding approaches and knowledge applications in the realm of social, racial and international relationships finds this civilization in danger of self-destruction by this self-same tremendous technological progress.

Historical Groups, February 13, 1951

Case 12. Lavoisier's Oxidation and the Overthrow of the Phlogiston Theory

Problem: How Could a Calx (e.g., Mercuric Oxide) Weigh More Than the Metal From Which it was Formed?

Historical Background:

1. Priestley had ignored the pertinent issue involved in the above question.
2. Lavoisier insisted upon making the above question an issue—implicit in his insistence was his Theory (and later, Law) of Conservation of Matter.
3. Other phlogistonists of the period countered by attributing a *negative weight* to Phlogiston to save their theory just as Neo-Galileans invented a *funiculus* or invisible thread to support Aristotle's "Nature Abhors a Vacuum" in Torricelli's barometer.
4. Lavoisier's answer based on his bold new interpretation of oxidation.[9]
   (a) That Priestley's "dephlogisticated air" was actually a new element which Lavoisier called Oxygen.
   (b) That such an element in the air in uniting through heat with a metal (e.g., mercury) resulted in compounds (e.g., mercuric oxide).
   (c) The explanation in (a) and (b) fitted the facts that "calces," that is, metal compounds or oxides, weighed more than the original metal without having to resort to the *negative weights* of the Phlogistonists.
   (d) The explanation in (a) and (b) also fitted a fact which the phlogiston theory did not, that as metals formed into calces, the volume of enclosed air could be shown to decrease.

Class Experimental Activity:

1. The students duplicated the experience of many metal workers and scientists before and during Priestley's and Lavoisier's time in finding that heated metals increase in weight. For convenience, the students used "steel wool" and magnesium ribbon.
2. The students further used the steel wool to test Lavoisier's 4. (d) above. A wad of steel wool at the bottom of a glass or tube inverted in a shallow container of water when heated or encouraged with acid to rust, caused the water gradually to rise up the glass or tube until the volume of air was reduced by about 20 percent.

Problem-Solving High Points:

1. Case 11 high points were seen to apply here.
2. Established theories were not overthrown by contradictory facts alone but by persistence in newer conceptions that better explain those facts.
3. Lavoisier's emphasis upon weights and *quantitative measurements* laid a solid basis for modern chemistry.

[9] Conant, *On Understanding Science*, pp. 74–96.

CONTEMPORARY GROUPS, FEBRUARY 15, 1951

Problem 12: Fire-Fighting with Water and Chemicals.

(a) What is Fire? What Happens to a Candle When It Burns?
(b) What are the Unique Advantages of Water in Fire-Fighting as Against Other Substances?
(c) For What Fires is Water Dangerous?

Preliminary Exploration: The above related questions were posed and various class ideas were compared and evaluated. The class differences were then resolved by such teacher-class planned experimental evidence as follows:

Experimental Evidence:

A. (1) The necessity of oxygen for a fire was shown by a candle flame which gradually died when enclosed in a glass jar. That it is the oxygen and not the nitrogen or carbon dioxide in the air that is essential for the flame were established by application of a flame to collected samples of these three gases.
   (2) Squares of cold, dry glass over candles caught the products of a candle flame, which were predicted by an equation involving the candle flame as a hot paraffin gas or vapor combining with oxygen.
   (3) Potassium hydroxide sticks were properly arranged on a beam balance, as a trap for the products of candles, the total weight on the pan was found to be greater by the addition of the combined oxygen, in illustration of the law of Conservation of Matter involved.

B. To compare various fire-extinguishing liquids, as carbon-tetrachloride, to water in respect to performance as a cooling agent,
   (1) match sticks or splints were equally soaked in these liquids, and then
   (2) held over equal flames to see which would longer retard the match or splint from burning.

C. (1) The dangers of water for oil fires were shown by applying water to a miniature oil fire on a small can. It became obvious that the water sank to the bottom of burning oil causing the burning oil to overflow.
   (2) A second equivalent fire was then shown to be smothered by a piece of cardboard.
   (3) A third equivalent fire was then shown to be smothered by vapor of carbon-tetrachloride.

Problem High Point Example: There is no all-answerable formula covering all situations. Object and ideas have advantages and disadvantages relative to given situations and purposes, which must be separately investigated, e.g., the danger of water for *oil* fires.

3. The Tests for Scientific Thinking

As the primary concern in this experimental study of effective use of the laboratory period was that of the development of scientific approaches to problems of everyday living, primary emphasis in testing was placed upon separate written and performance tests of scientific problem solving devised by the writer.

In the performance test in scientific problem-solving, the writer devised fourteen problem situations. Since evaluation of scientific problem-solving abilities was the objective in this test, technical skill and technical knowledge were held to a minimum as factors in the items. Three problems were invented to measure "accuracy of observation;" four set-ups, "determination of relevant factors, clues and cues in problem situations;" and seven situations to measure "resourcefulness in organizing relevant data, materials, and procedures.

In the administration of the test, each set-up was at its own clearly indicated station with its own problem question and instructions. In the performance test the students were allowed three and one-half minutes a problem with a half-minute warning bell to finish recording their answers. At a second bell, the students rotated to the next station, clearly marked. As examples of each of the three categories of these performance problems are the following copies of the direction cards:

Station 2

How Many Nails in This Container?

(a) Since you cannot expect to count all these nails in a few moments, *list the steps in proper order* that you would take in using this balance for a fairly close approximation of all the nails.
(b) What would be an assumption if you finally did have an approximate count of the nails?

Station 6

Symmetry Observation

Indicate in your answer book the number of lines in B that are missing to keep it from being exactly like A.

Station 11

"Dancing Mothballs"

On the basis of observation, what is your best lead as to why mothballs are able first to rise and then to sink in the liquid repeatedly?

The first example was one of "resourcefulness in organizing relevant procedures" in line with the purpose and the materials at hand. In the second example, the symmetrical pattern with its flaws was complex enough so that the student had to work systematically and quickly in order to obtain an "accuracy of observation" in the time alloted. In the third example, careful observation alone even without previous knowledge of the principle involved would inductively lead to the relevant cue or factor in the situation." Such "magic" exhibitions as this can occasionally be seen as advertising displays in the windows of shops.

In the construction of a written test for scientific thinking, the writer limited himself to evaluation of the following as a basic and balanced pattern in evaluation of scientific, that is, of open-minded, systematic, and critical thinking:

1. Ability to determine best leads or best authority for problem solution.
2. Ability to select and to organize relevant data and procedures.
3. Ability to interpret data with proper consideration for suspended judgment, hasty generalizations, and over-caution.
4. Ability to determine assumptions behind conclusions.

Open-mindedness of approach could be specifically provided for by (3) just above and systematization by (2). Critical abilities were involved in all four sections. Also, forms most suited for measurement of critical thinking and attitudes were used as Ralph Tyler's form of T, PT, ID, PF, F for interpretation of data and for associated attitudes of hasty generalization, suspended judgment, and over-caution.

Considerable efforts were made for increasing the validity of these tests. A select group of graduate students was used to establish an outside criterion for the written test that resulted in a validity coefficient of .68. The performance test showed a corre-

lation of .95 to the written test. Composite reliability coefficients of .52 and .60, respectively, were found for these two tests by the Jackson sensitivity method.

As pretests, the above written test for scientific thinking as well as the A.C.E. Psychological Test 1947, were used. The first served to remove the effects of any inequalities of initial problem solving abilities, while the second did the same for effects of inequality of general mental or academic ability. As secondary tests in subject matter content, outside criterion tests were introduced during the middle and at the end of the study. All of the measures used were significantly reliable at one per cent levels of significance.

4. SUMMARY OF EXPERIMENTAL METHODS AND RESULTS

The population of the study consisted of all students, mostly freshman and sophomores, regularly enrolled in the Natural Science IV and V sequence of the *Physical World* of physics, astronomy and chemistry at the University of Minnesota during Fall, 1950 and Winter, 1951. The original eighty-seven students were divided into five groups, two historical, two contemporary, and a supplementary demonstration group. All students attended the same three lecture periods each week. The laboratory or demonstration time was a single two-hour period a week.

Differentiation of methods was essentially in respect to problem treatment and materials. The laboratory courses consisted of fourteen contemporary problems parallel to fourteen case histories, all of which, in topic, were similar and concurrent to the accompanying demonstration group. The historical groups, however, involved historically centered problems and laboratory equipment; the contemporary groups involved contemporarily focused problems and equipment; and the demonstration group was apparatus centered in discussions, questions and problems with both contemporary and historical equipment. For example, in connection with the refraction of light, the historical groups worked on the Galilean telescope and its significance as empirical evidence in the Ptolemaic-Copernican issue of "Does the Sun Revolve Around the Earth or the Earth Around the Sun?" At the same time, the contemporary groups were considering their own eyes as optical instruments, particular optic defects that they may have developed, and correction by lenses. The demonstration group experienced standard class room refraction demonstrations.

Statistical treatment was based upon randomized sampling equalization of groups through Fischer's analysis of variance and co-variance, and provided for validity and reliability of measurement. The replicated historical and contemporary groups formed a 2 x 2 randomized block design. The demonstration group when combined with the pooled historical and pooled contemporary groups formed a secondary 3 x 1 randomized block. Preliminary data was obtained through the 1947 A.C.E. College Aptitude Test and a pretest on scientific thinking compiled by the writer. The final tests included (1) the written pretest repeated, (2) a "practical" or performance test based on fourteen actual problem situations for evaluation of open-minded, systematic, and critical thinking, and (3) outside criterion tests on science subject matter.

FINDINGS

1. In the use of the T-tests of significance to compare the written pretests to retests in scientific thinking, gains by each of the three groups were significant between 5 per cent to 10 per cent levels.

2. There were no significant differences between or among the methods in the two designs on the written scientific thinking test or on the outside criterion tests for science subject matter achievement.

3. On the performance test on scientific thinking, the contemporary laboratory group showed a general superiority over the other groups that became statistically significant at a 5 per cent level in the ability

to determine relevant factors and clues in problem situations.

5. IMPLICATIONS AND RECOMMENDATIONS

Among implications and recommendations to be drawn are the following:

1. There is further indication here that scientific thinking and scientific approach to problems can be learned through direct class room planning and procedures for the purpose.

2. There is here merely a first indication as to whether college teachers can better develop problem-solving abilities, attitudes, and resourcefulness for contemporary living by appreciatively and realistically duplicating and analyzing the problem-solving of some of the outstanding scientific thinkers of the past, or by working directly with students in immediate contemporary problems of science in various areas of living. In this first indication, the only significant advantage was in favor of the contemporary-laboratory group.

3. Whatever results we have seen here are based upon the one particular historical and the one particular contemporary problem-solving method developed. There are innumerable variations of such approaches to be tried. For example: What could be accomplished comparatively with historical materials used only to the extent that they throw direct light on contemporary problems? This, of course, would emphasize a developmental historical treatment that opens up into the modern scene rather than a more episodic case-history treatment.

4. We further recommend comparative studies of historical and contemporary methods for general education purposes in which not only the laboratory periods, but all class activities emphasize problem-solving processes. We can visualize, for example, a contemporary problem-solving treatment in which there is no set laboratory period, but in which laboratory or demonstration apparatus is brought into play right there and then whenever necessary or effective as evidence in class discussions, disputes, or other activities.

5. Although a performance test in scientific thinking was used, it was still under artificial controlled conditions of the classroom. There is room for combined, consistent efforts in further development of tests that approximate ever closer, actual living conditions or responses. For example, there might be objective testing techniques centered about evaluation of actual current newspaper advertising, editorials or the like.

6. In the evaluative studies in education, the more the experimenter can permit his classes to operate under normal teaching conditions instead of under controlled conditions typical of the experiment only, the more valid should be his results. Therefore, further development of statistical techniques that will enable a larger number of experimental variables to operate while determining and removing their effects from results, should be of additional benefit to educational research.

7. A pertinent question for further study regarding problem-solving objecti es and outcomes in the classroom has reference to accumulative educational effects. To what extent can a single course or section of a course with emphasis on scientific thinking procedures and outcomes, among other things, overcome habits of many years of past school experience of students based upon processes that involve essentially memorization and recall? To what extent would learning of a problem-solving type be accelerated with an accumulation of problem-solving experience in the students' educational background?

8. We might pose still another question for further study: To what extent and under what conditions is learning of a scientific problem-solving nature permanent, and what classroom procedures are more effective in such more permanent learning?

* * *

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CONTRIBUTIONS OF SCIENCE TO SELECTED PROBLEM AREAS PROPOSED FOR A PROGRAM OF GENERAL EDUCATION IN THE SECONDARY SCHOOL *

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INTRODUCTION

At the present time many attempts are being made to reorganize the secondary school curriculum to meet the needs of youth more effectively. Several factors are responsible for this movement. Among them are the following: (1) Evidence indicates that success in college does not depend on the pursuit of certain conventional subjects in the secondary school, and that about 80 per cent of the students do not pursue general education beyond the secondary school. (2) Educators have gained an increased understanding of the learning process, of the wider concept of method, and of the basic needs of the adolescent. Some of these attempts are within the pattern of "subjects" while others break more or less completely with the traditional conception of curriculum organization. As background for this article, the main types of the reorganized curricula will be briefly reviewed with an emphasis on the role of science in each of them.

Acting on the assumption that separate subjects take on new significance when they are interrelated, some schools have attempted to correlate certain subjects with others. For instance, science has been correlated with social studies in Edwin Denby High School (Detroit).[1] Teachers in these fields planned together, and the classes met for two consecutive periods daily. In the beginning, the lines between social studies and science were fairly closely drawn, but as time went on, the boundaries of both fields were disregarded. Topics studied included housing, social and national group problems, and social hazards. Various correlations of science with other subjects have been reported.

Taking one step beyond the correlated curriculum, some schools have developed certain units or unifying themes which are chosen because they afford the means of effectively teaching the basic content of certain subjects. In the Bronx High School of Science,[2] a committee of the English, social studies, science, art, mathematics, and music teachers, planned what was called an "integrated program" for attaining the aims of general education in the ninth grade. Learning experiences in these fields were organized around overarching units and the content of subjects was selected and taught with special reference to the chosen units. For instance, if the unit is

* Based on the author's dissertation with the same title for the degree Doctor of Philosophy, The Ohio State University, Columbus, Ohio, 1952.

[1] Anita D. Laton, and S. Ralph Powers, *New Directions In Science Teaching*. New York: McGraw-Hill Book Company, 1949, pp. 57–62.

[2] *Ibid.*, pp. 54–55.

"Health," the social studies classes consider such topics as costs of ill health to the individual and to society; changes through the ages of our ideas of health and disease; New York's protection of health through water purification, waste disposal, and curbing of smoke and noise, etc. . . . The science classes at the same time study the spread of communicable diseases, the developments in medicine with emphasis on the contributions of such men as Koch and Pasteur, modern methods of transportation as factors in spread of disease, the correction of popular superstitions and errors, and current scientific developments. In English, readings about the lives and work of men in the field of health are assigned.

Other schools have atempted to organize their curricula in terms of broad fields. The term "broad fields" refers to the uniting or "fusing" of separate subjects within a given subject-matter field. Besides the general science courses which are now well established, courses in physical science have been planned. In such courses the content of the conventional courses of physics and chemistry are fused. In the Central High School of Trenton (New Jersey),[3] biology and physical sciences were fused. The usual requirements of traditional elementary biology, physics, and chemistry were ignored, and a two-year course based on the students' needs was developed. The idea in teaching this course was to start with problems and then draw on whatever in the field of science seems appropriate.

THE CORE PROGRAM

A significant development in the direction of removing the barriers among the various subjects and developing a dynamic program based on the problems that confront youth in our confused culture is the core program which has been defined as "that aspect of the total curriculum which is basic for all students and which consists of learning activities that are organized without reference to conventional subject lines."[4] In content, the core consists of those problem areas most directly related to the common needs, problems, and interests of youth. From these problem areas learning units are to be developed cooperatively by teachers and students with activities organized without reference to conventional subject-matter lines. In this way the basic ideals, understandings, and skills are taught without compartmentalization, while guidance and counseling become an integral part of the day-by-day program of the school.

Perhaps an illustration of how a problem area may actually be used will clarify its role. A problem area such as *Personal and Community Health,* could either be assigned for consideration at a given grade level or could be one of a predetermined list of problem areas from which the class might choose, depending on the pattern of preplanning which is adopted. In preparing himself for teaching this problem area, the core teacher either by himself or preferably in collaboration with other teachers who represent various interests and have different competencies will prepare a kind of resource unit which serves as a reservoir for possible activities and instructional materials appropriate for teaching that unit. The actual class activities, however, would be planned cooperatively by the teachers and students.

Outside the core, which occupies from two to three hours daily, provision is made for special interest areas that are electives. The concern of such special interest areas is primarily the meeting of the students' specialized needs and interests, and secondarily, they contribute to general citizenship.

THE ROLE OF SCIENCE IN THE CORE NEEDS TO BE DEFINED

The theory underlying the development of the core program represents such a

[3] *Ibid.*, pp. 47–49.

[4] Harold Alberty, *Reorganizing the High-School Curriculum.* New York: The Macmillan Company, 1948, p. 154.

radical departure from conventional modes of curricular organization that the resulting gap between the old and the new cannot easily be bridged. The relation of the conventional subjects to the core has been an unsolved problem. In practice, the content of the core has been dominated by social studies and English. Thus, science, in spite of being an all-pervading aspect of human activity that would naturally be expected to be an integral part of any core program based on real life activities, has not yet played any significant role in the core program. The authors of the Forty-sixth Yearbook on the National Society for the Study of Education[5] discussed the difficulties involved in presenting an adequate program of science in the core and pointed out the fact that in the large majority of the schools in which the core is found, the teachers having major responsibility for constructing units of instruction are commonly teachers of social science and English.

THE PURPOSE OF THE STUDY

Sensing this problem, the writer has made a study for the purpose of sensitizing the core teachers—at the pre-planning level—to possibilities of using science for carrying out the core activities most effectively.

BASIC ASSUMPTIONS

1. The core program is an effective means of attaining the aims of general education.

2. Core teachers are capable, either through pre-service or in-service training of making use of the contributions of science to the problem areas.

LIMITATIONS OF THE STUDY

1. The contributions of science to the problem areas were developed according to the best judgment of the investigator. Admittedly, other investigators could add more contributions, or might modify or reject some of those set forth by the investigator.

2. It is impossible to define the actual rather than the potential contributions of science to the problem areas.

3. The environmental setting of a particular core program would influence the core activities and hence the science contributions, too.

PROCEDURES

1. Since the problem areas provide the basic framework for the core program, it was necessary either to formulate a set of problem areas appropriate for general education, or to accept some formulation already worked out. The list of sixteen problem areas developed by Lurry[6] as a part of her doctoral dissertation was chosen as the basis for this study since that list was validated by a jury of thirty educators in the field of core program development. Only minor editorial changes in that list had to be made. Following is the modified list:

I. Problems of Orientation to School Living
II. Problems of Self-Understanding
III. Problems of Developing Values and Beliefs
IV. Problems of Social Relationships in a Democracy
V. Problems of Employment and Vocation
VI. Problems of Conserving Natural Resources
VII. Problems of Education in American Democracy
VIII. Problems of Constructive Use of Leisure
IX. Problems of Family Living
X. Problems of Communication
XI. Problems of Democratic Government
XII. Problems of Personal and Community Health
XIII. Problems of Economic Relationships in a Democracy
XIV. Problems of Critical Thinking
XV. Problems of Achieving World Peace in the Atomic Age
XVI. Problems of Intercultural Relations

[5] *Science Education in American Schools,* Forty-sixth Yearbook of the National Society for the Study of Education, Part I. Chicago: University of Chicago Press, 1947.

[6] Lucile Lurry, "The Contributions of Home Economics to Selected Problem Areas in the Core Curriculum of the Secondary School" (Unpublished Doctoral Dissertation). Columbus: The Ohio State University, 1949.

2. As it was realized that contributions of science could not be listed without *first* determining posible student activities which might be utilized in developing a learning unit, extensive lists of suggested core activities for each of the sixteen problem areas were developed in the light of carefully formulated criteria. These activities were submitted to core teachers at the Ohio State University High School, for evaluation and suggestions. In the light of the comments received, some activities were modified or completely changed.

3. A careful reexamination of the core activities was made in order to determine what science contributions could be suggested. By science contributions it was meant those scientific facts, concepts, principles, instrumental or problem-solving skills, attitudes, appreciations, and interests that need to be *used* or *developed* in order that the respective activities might be carried out most effectively. Pertinent contributions were drawn from all sciences without regard to the arbitrary boundaries that separate one science from another. Most of the scientific contributions were listed under the heading "Scientific Understandings," since understanding is the critical element in developing most of the science objectives.

No attempt has been made to state what the scientific method could contribute to every activity, since it was assumed that this method would be central in the learning process, and could thus be considered a general contribution of science to education. For those activities, however, that were primarily developed for the purpose of attacking some phase of critical thinking, science contributions were stated under the heading "Problem-Solving Techniques." "Scientific Understandings" and/or "Problem-Solving Techniques" were listed directly following each of the core activities to which science could make a particular contribution. Following is an illustration of a core activity taken from *Problems of Family Living*, followed by the science contributions to that activity.

Plan a panel discussion on the topic: "What Should One Look For in a Mate?" Include such factors as: Health, heredity, education, cultural interests, socio-economic status, religion, and racial or national backgrounds.

Scientific Understandings

a. Health and heredity are very important factors in marriage. Outstanding biological obstacles to successful marriage include: hereditary deficiencies or blights in the germ plasm; acquired illnesses or physical incapacities which are serious enough to interfere with making a living or caring for a home; sexual inabilities or infertilities, such as impotency, frigidity, and sterility; immaturities in the physical development which may either mean that the person is too young for marriage or that there have been abnormal obstructions to the natural maturational processes and that medical or surgical attention is needed.

b. Eugnists believe that there is nothing wrong with cousin marriage so long as the ancestries of the mates are good; in such a case it may even result in superior offspring. If there are hereditary weaknesses, however, such as feeblemindedness in the family lines, cousin marriage is extremely dangerous.

c. Interracial marriages, though biologically unobjectionable are usually inadvisable on social and cultural grounds. Prejudice and cultural differences are obstacles to happy marriages.

4. In order to provide the reader with a comprehensive picture of the content of science in the proposed program, and to facilitate refering to them, the science contributions were reorganized under appropriate science categories.

5. The problem of determining the adequacy of the science contributions for general education was investigated. Although it was felt that supporters of the core program would regard the science contributions set forth in this study as adequate, since these contributions have potentialities for helping students in solving their prob-

lems, meeting their needs, and extending their interests, *three* criteria that would likely be acceptable to science educators as a basis for evaluation, were developed, namely:

a. Do the science contributions tend to realize the objectives of science education?

b. Do the science contributions harmonize with what science educators think the content of science in general education should be?

c. Do the science contributions have potentialities for preparing students for the pursuit of special interest science courses?

These criteria were applied to evaluate the potential adequacy of the science contributions for general education.

FINDINGS

Following are the major findings of this study:

1. Lurry's problem areas are so interrelated that activities assigned to one problem area might well be used in connection with other areas.

2. Science could contribute to thirteen problem areas. The extent of this contribution varied according to the nature of the problem area.

3. The suggested science contributions included 523 different statements that were classified under seven major categories. Following are these categories with the sub-headings under each to show its scope.

Health and Safety

Posture; Exercise, rest, and sleep; Nutrition; Overweight and underweight; Alcohol and tobacco; Communicable diseases; Disease control; Cancer; Oral hygiene; Hygiene of digestion; Hygiene of respiration; Hygiene of circulation; Hygiene of the skin and hair; Hygiene of the nervous system; Hygiene of the eye; Hygiene of the ear; Hygiene of sex; Emotions and health; Classroom hygiene; Community health; Occupational hygiene; Safety against fire.

Atomic Energy

Milestones to atomic energy; Structure of the atom; Fission in the atomic bomb; Disintegration of radioactive elements; Atomic terms; Nuclear scientists; Materials used in the atomic bomb; Secrecy of the atomic bomb; Atomic energy in war-time; Atomic energy in peace-time; Destructiveness of atomic bomb; National defense; Control of Atomic energy.

Conservation

Soil; Water; Minerals; Wildlife; Forests; Resource waste; Food supply.

Human Growth and Development

Prenatal life and heredity; Adolescence; Effects of endocrine glands on growth; Personality and heredity; Marriage.

Critical Thinking, Values, and Beliefs

The method of science; Science and religion; Science and morals; Superstitions; Scientific belifs; Beliefs about sex, courtship, and marriage; Beliefs about race and minority group relations; Evaluating sources of information; Consumer propaganda; Applications of the scientific method.

Communication

Broadcasting; Motion pictures; Technology and communication.

Hobbies

Minerals and rock collecting; Insect collecting; Ant observing; Growing plants without soil; Photography; Star gazing.

4. The science contributions were found to be potentially adequate for the purpose of general education. This conclusion was based on the following findings:

a. The science contributions tend to provide for growth toward the objectives of science education.

b. The science contributions encompass most of what science educators think *should* be included in science for general education.

c. The science contributions have potentialities of helping to prepare students adequately for the pursuit of special-interest science courses.

RECOMMENDATIONS

1. Teachers responsible for the core program should receive adequate training in science either on a pre-service or in-service level, so that they can use science more effectively for enriching their teaching.

2. The science teacher should be a member of the pre-planning committee so that the full contributions of science would be utilized.

3. The core teachers should study *all* problem areas, at the pre-planning stage.

GENERAL BIOLOGY AT THE KANSAS STATE TEACHERS COLLEGE OF EMPORIA

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This is a case study of a general biology course that serves the general education program of the college and also the major and minor sequences of the biology department. The course, *Biology* 1, *General Biology,* established on an experimental basis in 1945, was made a general requirement for the degree Bachelor of Science in Education, except for biology majors and minors, in 1946. Before 1946 there were eight beginning courses in the department—General Botany, General Zoology, Nature Study, Anatomy and Physiology, Entomology, Farm Crops, Livestock Judging, Bacteriology—any of which might contribute to the completion of a science group. Biology majors usually started with botany and zoology, five semester hours each. The usual major sequence now is biology, followed by botany and zoology, three hours each. *Biology* 1 is now required for the degrees Bachelor of Science in Education, Bachelor of Science in Business, Bachelor of Music Education, and Bachelor of Arts, also for several preprofessional programs. It is occasionally taken as an elective on a special program.

As a result of experience with this course, the biology staff of the college has committed itself to the philosophy that the general broad overview of the life sciences that is good for the educated citizen is also the best start for the prospective major in anatomy, bacteriology, botany, entomology, physiology, zoology or any other biological science, for a premedical or predental student, or anyone else who plans to use biology vocationally.

There are many advantages in offering a single course for both majors and nonmajors. Some of the more important may be listed:

1. A single course is more easily managed. Enrollment is less complicated, fewer sections are necessary, laboratory equipment is easier to keep in order and schedules are easier to maintain.

2. The problem of what to do with the student who becomes interested in biology as a result of enrollment in the required courses is solved. At Emporia State he simply goes on with one of the next courses—botany, entomology, zoology or whichever else is most practical and convenient at the time. He has lost no time and is at the same stage in his progress as if he had decided in the first place to be a biology major.

3. Interest and tone is given to a class, especially in the laboratory, by having in each section a few students who are already enthusiastic about biology. When a student asks "Why in the world do I have to take this course?" the teacher's explanation may fall flat, but the answer from an enthusiastic fellow student is usually taken seriously.

4. The "down-the-nose" attitude of the biology majors (and unfortunately also sometimes the biology teachers) toward the required course does not exist. All are in the same boat together.

5. The major or minor student is apt to make his next choices more wisely as a result of this course. Formerly we had some difficulty getting zoology students to take botany and vice versa. Most students now see the implications of each science and enroll in both at the earliest opportunity.

6. The biology major or minor gets a better view of the interrelations and applications of his chosen science than he is apt to get from the traditional courses which

were directed immediately toward specialization.

7. All the teachers involved in the course take a broader view of the entire field of biology. This may well be the most important advantage of all.

OBJECTIVES

The objectives of *Biology* 1 have been reworded and revised several times, but the basic ideas have remained the same. They are essentially as follows:

1. To help the student understand himself, in terms of the living world of which he is a part and in the light of the past development of life on the earth.
2. To acquaint him with the basic principles of biology that are apt to be encountered in his everyday life as a citizen.
3. To acquaint him with the technical terms of biology which appear with some frequency in newspapers, magazines, radio broadcasts and other non-technical sources.
4. To explain the practical and economic relationships of plants and animals including the conservation of living resources.
5. To develop an appreciation of the laboratory method of obtaining knowledge and of the methods, techniques, and principles involved in scientific study.
6. To give the student a basis for intelligent selection of further courses in the biological sciences.

SELECTION OF CONTENT

It is generally agreed that the meat of a general education course in science should be scientific facts, methods, and principles—not something *about* facts, methods, and principles. To that end, we try to keep the content of *Biology* 1 informational and objective. A wealth of living organisms, as well as charts, models, slides, and other teaching and learning aids is available. The student is given every opportunity of comparing for himself the actual things and what the books say about them.

Only a small part of the available subject matter of biology can be included in a one-semester course. At first we tried to select teaching units from the various biological sciences, but this plan was soon dropped. The field of biology is too diverse. With selection on the basis of sampling of each biological science, the course was too thinly spread.

Instead of selection of parts from each of the dozen or so biological sciences, it was decided to choose teaching areas that would meet certain tests set up from a study of the objectives of the course. The latter are relatively few and fairly clear cut.

Any body of subject matter, to be included in *Biology* 1 must pass one or more of the following tests:

1. It must illustrate one of the basic biological principles mentioned in (2) above; for example, the cellular structure of living things, or the building of food by green plants.
2. It must have some important bearing on health and general body welfare; for example, the germ theory of disease, or nutrition.
3. It must have some important practical or economic bearing; for example, types and methods of insect control, or parasitic organisms.
4. It must be something of obvious popular interest; for example, human heredity, or poisonous plants and animals.
5. It must be rated by students as of primary interest and importance; for example, the principles of heredity, or life processes.
6. It must be necessary for the understanding of one or more of the above; for example, cell division, which is studied as a background for the study of heredity and the development of the embryo.

The content of the course has been revised from time to time on the basis of student and faculty evaluation. No fundamental changes have been made, but many points of emphasis have been changed. Some items have been dropped and others included.

GENERAL PROCEDURE

Biology 1 meets twice a week in lecture sessions and once a week in two-hour laboratory session. For lectures students meet in groups of 35 to 75; in the laboratory the maximum number is 24, but an effort is made to have 20 or less per section.

The laboratory period comes between the Monday and Friday lectures of each week. The topics covered in the last several spring semesters are about as follows, with some variation from year to year.

hand during the entire laboratory periods, one in each section. They help the instructors with all laboratory routines, instructional as well as technical. The more experienced ones do some actual teaching.

Week	Monday Lecture Topic	Laboratory	Friday Lecture Topic
1.	(Enrollment)		Scope and objectives of biology
2.	Structure and function in living things	Use of the Microscope	Cellular structure of living things
3.	Protoplasm, the stuff we are made of	Cells and protoplasm	Test
4.	Metabolism; how living things work	Life processes	Food and digestion
5.	Vitamins	Food and digestion	Algae, simple food-making plans
6.	Microbes, beneficial and harmful	Simple microorganisms	Disease producers and how to fight them
7.	Fungi, simple independent plants	Yeast, molds, bacteria	Reproduction by cell division
8.	From egg to individual	Cell division and early embryology	Test
9.	Protozoa, one-celled animals	The animal kingdom	From one-celled to many-celled animals
10.	The parasitic habit of life	Simple worms, parasites	The beginnings of complex animal organization
11.	The largest animal group	The crayfish and the principle of homology	The vertebrate body plan
12.	The classes of vertebrates	The frog as a typical vertebrate	(Spring vacation)
13.	(Spring vacation)	The plant kingdom	The principle of alternation of generation
14.	The evergreens and their allies	The seed plants	The flowering plants
15.	Test	Field trip	Organisms and their environment
16.	The Mendelian "laws"	Genetics problems	Human heredity
17.	Conservation	Review	Review

In the fall semester, the first laboratory period is devoted to the field trip, followed by periods on the plant kingdom and seed plants. In the summer, with full 60-minute hours in an eight week period, we combine some of the laboratory periods and present others in the form of demonstration lectures. The chronological sequence is about the same as that of the spring semester.

All instructors and laboratory assistants involved in the course meet weekly; this insures joint planning and a high degree of coordination among the different lecture and laboratory sections.

The laboratory assistants, most of whom are junior or senior biology majors, are on

Tests are given frequently. Those in lecture periods are full period length, and in most cases all students take the same test. There are about ten laboratory tests per semester. These are about 20 minutes long and are different for each section, although equated for difficulty as nearly as possible.

A standard textbook in general biology is used. The student is given an assignment sheet at the beginning of the semester, including both lecture and laboratory assignments for the semester. The laboratory manual, produced locally, includes 15 laboratory exercises, as indicated in the schedule above.

We have not been greatly concerned as to whether the presentation is entirely logical or exactly balanced between types and principles, or between plants and animals. We no longer consider this relatively important. We have selected laboratory exercises that (1) get certain points across, (2) are practical to operate in groups, (3) are not too expensive, (4) are not too dull or heavy, and (5) can be handled, with a minimum of coordination difficulties, by a group of different instructors and laboratory assistants. We have not dodged any because they were too difficult. Our experience has been that if the students can be kept interested, the work automatically becomes less difficult.

EXEMPTION

Students exceeding a certain score on the biology entrance test, given at the beginning of the freshman year, are exempt from *Biology* 1 and may enroll in any other biology course for which *Biology* 1 is the only prerequisite. The exemption line is determined on the basis of performance by students in the course in previous semesters. Each semester the final examination is made up partly of questions selected from previous entrance tests, and each entrance test includes many items taken from previous final examinations. The items are selected on the basis of the relative difficulty and consistency of results on error studies. On three occasions the whole entrance test of one year has been used for the final examination of the following year. Thus a complete item-by-item comparison could be made.

The line is drawn at such a level that it exempts any student who could at the time of entrance have passed a final examination with a grade of C— or better.* We have not attempted to validate this particular criterion; however it seems to be sound, judging from indirect evidence. Little information was found on this matter; it evidently needs more study.

* We use grades of A, B, C, D, and F. C— is somewhat below average.

For the past year the above procedure indicated that 12 per cent of the entering class could have passed the final examination with a grade of C— or better. This percentage has varied from time to time, but it has not been below 11 per cent or above 14 per cent.

We have only scanty data on the relation between high school biology and the exemptions, or on the performance of the students who took biology in high school as compared with those who did not. Both problems are under investigation.

Space does not permit including the whole entrance test, but a few sample questions follow.

True-False

1. The mosquito is the intermediate host of the malaria germ.
2. Green plants make their own food from non-living materials.
3. Some of the one-celled animals have combinations of plant and animal characteristics.
4. Viruses are slightly larger than bacteria.
5. Most types of bacteria cause disease, either in man or in other animals.
6. The roots of living plants take in oxygen and give off carbon dioxide.
7. The spores of wheat rust are scattered largely by insects.

Multiple Choice

1. Carriers of yellow fever: 1. mosquitoes, 2. flies, 3. ticks, 4. snails, 5. fleas.
2. A distinguishing feature of poison ivy; 1. leaflets in five's, 2. leaflets in three's, 3. leaflets with smooth edges, 4. compound leaves, 5. red berries.
3. Plants that harbor soil-building bacteria: 1. grasses, 2. sunflowers, 3. clovers, 4. small grains, 5. corn.
4. When male and female animals of different species are mated, the hybrids: 1. die before birth, 2. are unable to develop to maturity, 3. are sterile. 4. are fertile, 5. may be any of these depending on the species involved.
5. Not a necessary factor for seed germination: 1. oxygen, 2. moisture, 3. seed enzymes, 4. light, 5. suitable temperature.
6. In animals and in most plants, release of energy from foods is brought about by: 1. digestion, 2. excretion, 3. fermentation, 4. photosynthesis, 5. oxidation.
7. Food with the largest number of calories per ounce: 1. carrots, 2. eggs, 3. bacon, 4. lean steak, 5. candy bar.

An exempted student who expects to take further biology courses is interviewed and sometimes given further tests. If there

are gaps in his knowledge which might interfere with his satisfactory progress in later courses, he is advised to take *Biology* 1 before going further. In any case, exemption does not bar a student from the general biology course; it gives him the privilege of skipping it.

EVALUATION

I. Grading

The grade in the course is determined by lecture tests, laboratory tests and performance, and a final examination. The relative weights of these have varied somewhat, but for several semesters we have used the following: lecture tests—40 per cent, laboratory tests and performance—40 per cent, final examination—20 per cent. All tests are returned to the student for inspection and he may find out at any time where he stands in relation to his section or to the entire class.

II. Student Evaluation

At the end of the semester each student is invited to fill out a course evaluation sheet. He does not sign his name (he may if he chooses) but he does indicate, as will be seen from the form shown below, his classification and reason for taking the course. The details of the sheet have changed somewhat, but the form shown below has been in use, except for item 7, for the past six years.

Other types of evaluation are in progress or being planned, for example opinions from seniors or from graduates who took only the required biology. It is hoped that responses from those who have completed or nearly completed their college education will show what these persons think *Biology* 1 has contributed to them as educated citizens.

The student evaluation blank, as currently in use, follows. In its mimeographed form, it allows the student plenty of space to write any comments he wishes.

( ) 1. Classification: 1. freshman, 2. sophomore, 3. junior, 4. senior, 5. other or unclassified.
( ) 2. Reason for taking course: 1. general requirement, 2. biology major or minor, 3. preparation for medicine or allied field, 4. preparation for agriculture, forestry or allied field, 5. other.
( ) 3. Amount of work in proportion to other three-hour courses: 1. more, 2. less, 3. about the same.
( ) 4. Amount of laboratory work: 1. too much, 2. not enough, 3. about right.
( ) 5. Number of laboratory tests: 1. too many, 2. not enough, 3. about right.
( ) 6. Number of lecture tests: 1. too many, 2. not enough, 3. about right.
( ) 7. To make the course more useful, should we: 1. cover fewer topics, more thoroughly? 2. cover more topics, in less detail? 3. leave the organization of topics as it is?
8. Topics of greatest importance:
9. Topics of greatest interest to me:
10. Topics of least importance:
11. Topics of least interest to me:
12. Topics that were most difficult:
13. Suggestions for improvement of course:

Student evaluations brought some surprises. We had thought that the students taking the course as a general requirement (hereafter referred to as "general" students) would react quite differently from those with a professional or personal interest (hereafter referred to as "professional" students) in the subject, but the differences thus far shown have been slight. At only a few points was there enough difference to be even doubtfully significant. The two groups agreed as to the proportionate amount of work as compared to other three-hour courses, the relative amount of laboratory work, the number of lecture and laboratory tests and the procedures for improving the course. They ranked the most and the least important, the most and least interesting and the most difficult topics in approximately the same relative order. The "general" students seem slightly more interested in the practical and human interest phases of biology, and the "professional" ones somewhat more in the taxonomic and technical, but the differences were certainly not what we expected.

COMPILATION OF STUDENT OPINION

The combined compilation which follows covers the past six semesters. During this period the organization of *Biology* 1

has been relatively stable and the student responses have not changed much from semester to semester. Ratings are included from 1,063 students, which is almost 95 per cent of the 1,124 enrolled for those periods. The totals are not all 1,063, because many students did not fill in all the blanks.

tests, and course organization, are shown in Table II.

To us the most noteworthy feature of the data in Table II is the similarity between the responses of the two groups of students. We were expecting considerable differences. Evidently the students who

TABLE I

RESPONSES TO ITEMS 1 AND 2, CLASSIFICATION OF STUDENTS AND REASONS FOR TAKING COURSE

Classification	Number	Per Cent	Reason for Taking Course	Number	Per Cent
Freshman	341	32	General requirement	818	77
Sophomore	507	48	Biology major or minor	99	9
Junior	172	16	Preprofessional	132	13
Senior	35	3	Elective	11	1
Not stated	8	1	Not stated	3	..
Total	1063	100	Total	1063	100

The responses to items 3 to 7, in which the students expressed their opinions about the amount of work in *Biology* 1 as compared with other courses, the amount of laboratory work, laboratory and lecture

plan to use biology professionally hold the same opinions about these phases of *Biology* 1 as do the general students. It must be borne in mind that the course is designed for general education. It is not "the first

TABLE II

RESPONSES TO ITEMS 3 AND 7, CONCERNING AMOUNT OF WORK IN THE COURSE, AMOUNT OF LABORATORY WORK, TESTS, AND COURSE ORGANIZATION

		"General" Students		"Professional" Students	
		Number	Per Cent	Number	Per Cent
Item 3. Amount of work in comparison to other three hour courses	more	231	28	50	21
	less	65	8	43	18
	about same	522	64	147	61
	total	818	100	240	100
Item 4. Amount of laboratory work	too much	142	17	37	15
	not enough	94	12	30	13
	about right	582	71	174	72
	total	818	100	241	100
Item 5. Number of laboratory tests	too many	218	27	66	27
	not enough	38	5	14	6
	about right	557	68	160	67
	total	813	100	240	100
Item 6. Number of lecture tests	too many	7	1	0	0
	not enough	273	33	100	41
	about right	535	66	142	59
	total	815	100	242	100
Item 7. To make the course more useful	cover fewer topics	132	41	31	38
	cover more topics	84	26	20	24
	leave course as it is	107	33	31	38
	total	323	100	82	100

course in a sequence" planned for future biologists, although students who choose to go further in biology do take *Biology* 1 before taking any of the courses planned specifically for them.

In the next six tables (III to VIII) the data are presented as total number of responses, with the items ranked in the order of frequency of mention by the "general" students. Some or all of the blanks were filled in by about 55 per cent (589) of the students. Of these 433 were "general" and 156 "professional." The total number of responses is far above 589 because many students mentioned more than one topic in a category.

Comparison of Tables III and IV indicates that students thought their favorite topics were also the most important. There are a few exceptions, however. While 52 students listed reproduction as a topic of greatest importance, only 12 listed it as a topic of greatest interest; anatomy and dissection, listed as most important by only 12 students, was thought most interesting by 49; vertebrates, considered most important by 27 students, were not even mentioned among the most interesting topics.

TABLE III

Responses to Item 8. Topics of Greatest Importance (479 Responding)

	"General" Students		"Professional" Students	
	Number	Rank	Number	Rank
Genetics	264	1	89	1
Animals, animal life	100	2	32	3
Life processes	98	3	23	5
Plants, plant life	97	4	36	2
Microorganisms	60	5	18	6
Human biology	48	6	4	11
Nutrition	45	7	14	7
Reproduction	45	7	7	8
Classification	40	9	7	8
Disease control	39	10	26	4
Vertebrates	24	11	3	12
Evolution	12	12	7	8
Practical biology	11	13	3	12
Conservation	10	14	3	12
Anatomy, dissection	10	14	2	15

Nineteen other topics were listed 10 or less times each.

TABLE IV

Responses to Item 9. Topics of Greatest Interest to Me (508 Responding)

	"General" Students		"Professional" Students	
	Number	Rank	Number	Rank
Genetics	379	1	72	1
Animals, animal life	112	2	44	2
Plants, plant life	104	3	31	3
Life processes	97	4	22	6
Microorganisms	77	5	29	4
Nutrition	66	6	22	6
Disease control	48	7	12	8
Classification	43	8	26	5
Anatomy, dissection	39	8	10	9
Evolution	28	10	9	10
Insects	26	11	6	12
Body systems	9	12	9	10
Conservation	9	12	5	12
Human biology	9	12	4	14
Reproduction	9	12	3	15

Twenty-five other topics were listed 10 or less times each.

TABLE V

RESPONSES TO ITEM 10. TOPICS OF LEAST IMPORTANCE (482 RESPONDING)

	"General" Students		"Professional" Students	
	Number	Rank	Number	Rank
Lower animals	163	1	32	2
Lower plants	134	2	42	1
Microorganisms	105	3	26	5
Classification	101	4	15	7
Parasites	83	5	27	4
Insects	70	6	12	9
Dissection	46	7	15	7
Life processes	33	8	6	11
Worms	32	9	29	3
Technical names	26	10	9	10
Evolution	14	11	6	11
History of biology	7	12	18	6
Conservation	6	13	5	13

Fifteen other topics were listed 10 or less times each.

TABLE VI

RESPONSES TO ITEM 11. TOPICS OF LEAST INTEREST TO ME (480 RESPONDING)

	"General" Students		"Professional" Students	
	Number	Rank	Number	Rank
Lower plants	164	1	45	1
Lower animals	157	2	40	3
Microorganisms	135	3	44	2
Classification	97	4	20	6
Worms	94	5	32	5
Insects	90	6	36	4
Dissection	63	7	19	7
Parasites	51	8	17	8
Life processes	30	9	6	10
Plants	21	10	10	9
Technical names	12	11	5	11
Animals	10	12	3	12
Conservation	9	13	2	13

Twenty-three other topics were listed 10 or less times each.

TABLE VII

RESPONSES TO ITEM 12. TOPICS THAT WERE MOST DIFFICULT (480 RESPONDING)

	"General" Students		"Professional" Students	
	Number	Rank	Number	Rank
Genetics	240	1	64	1
Classification	209	2	61	2
Life processes	137	3	21	8
Reproduction	132	4	22	7
Microorganisms	100	5	43	4
Disease control	91	6	44	3
Vitamins	70	7	41	5
Technical names	56	8	24	6
Bacteria	31	9	16	9
Nutrition	19	10	9	10
Parasites	17	11	2	13
Anatomy, dissection	15	12	6	11
Plants	12	13	4	12
Life histories	10	14	2	13

Nine other topics were listed 10 or less times each.

Tables V and VI show that the students considered of least importance the topics they disliked. The agreement between dislike and low importance rating is greater than that between interest and high importance rating. Students may be more discriminating in their judgments of topics they consider important and interesting than those which they think are unimportant and uninteresting.

It has often been said that students like those topics that are easy for them, but the data in Table VII do not show this. It seems that the students discriminated rather carefully between what they thought was difficult and what was of little interest. For example, genetics, which was rated far ahead of any other topics in both importance and interest, was also rated first in difficulty, while classification, which was rated low in importance and interest, was rated second only to genetics in difficulty. Evidently, the students did not rate a topic as important or interesting merely because it was hard or easy for them; there is a conspicuous lack of agreement between the ratings in Table VII and the ratings of the corresponding topics in the four preceding tables.

A total of 525 students responded to item 13, suggestions for improvement of the course. This was the largest number of responses to any of the write-in items. However, of the 525, 289 said "leave the course as it is" or words to that effect, leaving only 236, or 22 per cent, who actually made any suggestions for improvement. Of these 236, 192 were "general" and 44 "professional" students. Some of the suggestions were full page statements including several separate points; others were only a word or two. All the suggestions were placed in 22 categories, as shown in Table VIII. A few students suggested changes over which the Biology Department has no control or which are impossible for reasons of scheduling or availability of rooms; these are not included in Table VIII.

It will be noted that the suggestions in Table VIII deal more with teaching and curricular procedures than with topics taught.

With regard to topics taught, Table VIII

TABLE VIII

Responses to Item 13. Suggestions for Improvement of Course (236 Responding)

	"General" Students		"Professional" Students	
	Number	Rank	Number	Rank
Include more human biology	54	1	20	1
Include more genetics	50	2	19	3
Cover fewer topics	44	3	19	3
Have more lab work	43	4	20	1
Have more lecture tests	30	5	10	8
Have smaller lab sections	29	6	12	5
Learn fewer technical names	26	7	9	9
Have more field trips	26	7	9	9
Have more practical biology	24	9	9	9
Make tests more general	24	9	12	5
Have biology before health education	19	11	8	12
More correlation between lecture and lab	15	12	11	7
Biology before psychology	14	13	5	15
Make work more technical	10	14	4	18
Stress plants more	10	14	8	12
Stress microbes more	9	16	5	15
Lecture more in lab period	8	17	6	14
Have more dissection	7	18	6	14
Have more sex education	6	19	4	18
Relate biology more to physical science	6	19	4	18
Teach less chemistry	6	19	2	21
Relate biology more to social science	2	22	1	22

is in general consistent with Tables III to VI, but with some exceptions. For example, the suggestion made most often was to include more human biology, although this topic was rated nowhere near the top in importance and interest.

SUMMARY

1. At the Kansas State Teachers College of Emporia, *Biology* 1, *General Biology*, which is a part of the general education requirement of the college, is also a prerequisite for all other biology courses.

2. The content of the course is determined by certain criteria based on the objectives of the course.

3. The course, for three semester hours credit, meets in two lecture periods and one two-hour laboratory perior per week.

4. On the basis of an examination given at the time of entrance to the college, about 12 per cent of the entering freshmen are exempted from *Biology* 1.

5. The students are asked to evaluate the course at the end of the semester.

6. Tabulated results from 1,063 student ratings are presented; these represent 95 per cent of the students enrolled in *Biology* 1 during an eight-semester period.

THE TREATMENT OF IONIZATION IN GENERAL CHEMISTRY TEXTBOOKS, 1887–1940[1,2]

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TEXTBOOKS exert a very profound effect on the teaching of a subject, both what is taught and the way it is taught. The large majority of teachers use books written by someone else, and it is probably safe to assume that most of them "follow the text" fairly closely. Therefore, it was felt that it might be worth while to see how some important topic has been treated in a number of general chemistry textbooks over a period of time. Ionization was the topic selected and it was chosen partly because the date of Arrhenius' theory gave a good starting point for the study.

Arrhenius' theory was published in 1887 and the Debye-Huckel theory about thirty-five years later. When were these theories incorporated into general chemistry textbooks, how were they treated, how has the treatment varied, and what was the opinion of the author in each case? Did he believe that the theory of Arrhenius was adequate, or the Debye-Huckel, neither, or both? The textbooks examined were all published in the United States and were on the college level. An effort was made to space the books, according to publication date, as uniformly as possible from 1887 to about 1940, except that the periods immediately following the announcements of the two theories were covered more thoroughly. Although it was not possible to obtain all of the books that were wanted, about fifty-five were examined; and, of that number, thirty-one have been used in this study. Both introductory and advanced chemistry texts were used. It was found that in some instances the introductory texts treated the material on the theory of ionization more thoroughly than did some of the advanced texts of the same period, and for this reason no attempt at grouping the books according to "advanced" and "introductory" texts was made.

Some of the early textbooks made ref-

[1] This paper was prepared by Auborn Russ Hall during a senior course in Independent Study at Huntington College, Montgomery, Alabama.

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erence to the theories of electrolytic dissociation which preceded that of Arrhenius, and four texts published in 1869, 1882, 1884, and 1885, were examined to determine what treatment was given these theories. It appears that the theory of Clausius was the prevailing one when Arrhenius began his work on electrolysis. The revolutionary view that substances that are the most active chemically are those that are the most dissociated was met with passive resistance by the older heads who were accustomed to thinking in terms of atoms and molecules as being the only units which took part in chemical reactions. It appears that the two most disturbing factors of this new theory were: Where is the source of the charges on the ions, and if sodium chloride is dissociated in solution, why are there no identifiable properties of the metallic sodium and the gaseous chlorine exhibited by the solutions? The earlier textbooks usually gave considerable space to answering these two questions [20], [15], [2], [26].

Ira Remsen's 1889 *Inorganic Chemistry* was the first text examined after the appearance of Arrhenius' theory. In his discussion of electrolysis, Remsen showed familiarity with Clausius' theory of electrolysis. This book was the first examined which gave equations, minus the charges, of course, to illustrate the breaking down of a substance into its constituent radicals during electrolysis. Remsen suggested that the existing theories were inadequate, but he offered no speculation about the matter [23].

Alfred A. Bennett's *Inorganic Chemistry* published in 1892 in two volumes devoted approximately one page to the theory of electrolysis. The author defined dissociation as "the separation of a more or less complex compound into its elements or into less complex molecules" [1]. Bennett did not mention the Arrhenius theory.

A very generalized discussion of electrolysis was found in Freer's *Descriptive Inorganic General Chemistry,* published in 1894. The author's explanation of electrolysis was that when a compound formed of a metal and a "not-metal" is subjected to the action of an electric current, the metal and the "not-metal" will separate, the former going to the negative pole and the latter to the positive pole [5].

Tillman's *Descriptive General Chemistry,* published in 1897, was designed to meet the requirements of a short course in general chemistry being taught at the U. S. Military Academy at West Point. Examination of this text revealed that Tillman did not include any discussion of the theory of ionization. Two years later, however, a revised edition of the book appeared, and although the texts throughout were essentially the same, the author had added a chapter to his later edition entitled "Affinity" in which he discussed the theory of solutions, electrolysis, electrolytes and their osmotic pressures, and the results of ionization. In the revised edition Tillman devoted four pages to the theory, using illustrations only of the abnormal osmotic pressures of aqueous solutions of acids, bases and salts to support the theory, but he did mention that solutions of these substances exhibit abnormal freezing points. The treatment was not mathematical, and there was no mention of Arrhenius in connection with the theory [28], [29].

Remsen's revised text, published in 1898, was the first to give the salient points of the Arrhenius' theory. The author gave approximately six pages to the phenomena of electrolytic dissociation, explaining that electrolytes are "at least to some extent" decomposed into their constituent ions when they are dissolved, and that these ions, which are charged with electricity, transfer their charges in the solution and thus conduct the current. He was of the opinion that reactions of this type "are reactions of ions and not of elements or compounds." To support the theory the author gave three experimental factors, i.e., the heat evolved in neutralizing equivalent quantities of all acids at infinite dilution is always the same, and solutions of electrolytes exhibit abnormal freezing and boiling

points. Remsen said that recognition of these facts led Arrhenius to the idea that electrolytes are dissociated in solution and that "this idea is likely to revolutionize the views of chemists in regard to the action of chemical substances upon each other in solution" [24].

A text by Harry C. Jones, published in 1903, gave approximately three pages to the theory. This was the first book examined which recommended attaching charges to the ions, and the author wrote the equations as follows: $HCl = H+, Cl—$. He explained that the comma between the two ions means that they come from the same molecule and will unite again and form the original molecule when the water is removed. Under a sub-title "Importance of the Theory of Electrolytic Dissociation for Chemistry" Jones said that there is an overwhelming amount of evidence in favor of the theory, but that the scope of his book did not allow him to present it. He apparently later decided that he must reiterate the importance of the theory and the limited scope of his text, for as a postscript to the last, and unrelated chapter he added the subtitle "Nature and Role of Ions in Chemistry" under which he stated, "The importance of the ions in chemistry has come to be recognized in the last few years. It is now quite certain that most reactions in inorganic chemistry are reactions between ions, molecules as such having nothing to do with the reactions" [9]. No experimental basis of Arrhenius' theory was presented.

It was evident from the texts that Arrhenius' theory was growing in importance because more and more space was being given to the treatment of electrolysis, but only one book thus far has mentioned Arrhenius in the discussion. McPherson and Henderson's text of 1905 devoted six pages to the "Theory of Electrolytic Dissociation." The authors set forth five so-called "assumptions" of the theory, and in support of it gave experimental data on the abnormalities of the freezing points and boiling points of electrolytes. The treatment was not mathematical [17].

According to John H. Long, author of *Elements of General Chemistry,* published in 1906, the theory was but "a working hypothesis which is convenient because of the large number of phenomena which it correlates" [16]. Long gave by far the most thorough treatment of all the texts examined up to this date. He explained the differences between ions and the ordinary atoms, and attempted to answer the question which apparently all chemists were asking at that time and the one which had baffled them since the Arrhenius theory was postulated, i.e., that of the source of the charges of the ions. Long said, "It is likely that the dissolved molecules contain the two charges in balanced or saturated condition and the function of the solvent is to separate the component atoms . . ." [16]. This was the first text to derive the equilibrium constant from the law of mass action and the first to mention solubility product in connection with the theory. The author defined solubility product as "the term applied to that product of the ion concentrations which cannot be exceeded without throwing some of the dissolved salt out of solution" [16]. Seven pages were devoted to a discussion of the theory.

A third text by Tillman, published in 1907, gave eighteen pages to the theory. It will be remembered that this book was designed for a two months' course in the study of general chemistry. To support the theory, Tillman gave the usual experimental data on the abnormal freezing point lowering, boiling point elevation, and osmotic pressure exhibited by electrolytes. Again there was no mention of Arrhenius in the treatment of the theory [30].

Of the books examined during the first decade of the 20th century, Remsen's 1908 edition has been chosen as representative of the general outline of treatment the theory was receiving. The Arrhenius theory had not yet acquired a separate chapter for itself and continued to be discussed under the title "electrolysis." The discus-

sion was usually opened with the differentiation of the two types of conductors, metals and aqueous solutions of acids, bases, and salts. Then came definitions of electrolysis, anodes and cathodes, and ions and ionization. Faraday's name appeared in the discussion much more frequently than did Arrhenius', because a general statement of Faraday's contributions nearly always preceded a statement of the theory. It will be noted that only once in the texts examined thus far has Arrhenius been mentioned. Faraday's first and second laws always received a more orderly and concise treatment than did the theory of ionization. During this period the texts devoted considerable space to an explanation of the difference between an atom of a substance and an ion of the same. Remsen's explanation was typical. "Ions are conceived as matter charged with electricity while the same matter in its ordinary state is not charged with electricity; hence the ion of a substance differs from the non-ionized substance by the electric energy of its charges" [22]. After the lengthy experimental data of Faraday's work were set forth, data to support the theory of "electrolytic dissociation," such as abnormal lowering of the freezing point, elevation of the boiling point, and osmotic pressure of solutions of electrolytes were given. Many of the authors pointed out, as did Remsen, that the electric current was not the cause of the decomposition of the electrolyte into ions, and that "electrolytes are at least to some extent decomposed into their constituent ions when they are dissolved in water, the extent of this breaking down being determined primarily by the concentration of the solution; the greater the dilution, the greater the dissociation" [22]. Never was found the statement so common to modern texts that "reaction between solutions of electrolytes is due to the interaction of ions," but always "it is *probably* due to the ions," and "it is probable that, so far as the compounds are present in the undissociated condition they do not act upon each other" [22].

New definitions of acids and bases in terms of the theory were common. Remsen defined an acid as "a substance which contains hydrogen, which it easily exchanges for a metal, when treated with a metal itself, or with a compound of a metal, called a base," and a base was defined as "a substance containing a metal combined with hydrogen and oxygen. It easily exchanges its metal for hydrogen when treated with an acid" [22].

Throughout the first decade of the 20th century, nearly a quarter of a century after the Arrhenius theory appeared, not a single textbook examined gave an indication that experimental work in the field was beginning to show that the theory might be modified to apply to strong electrolytes. Remsen's 1899 edition did suggest that the theory was inadequate, but he did not explain in what way, and his 1908 text gave no suggestion that it might be modified.

One of the most interesting and rewarding features of this study was the discovery of two texts by Louis Kahlenberg, one published in 1910 and another in 1918, which set about to prove the Arrhenius theory untenable, and in the first edition the author devoted fifteen pages to his attempt. Kahlenberg began his attack on the theory in a discussion of precipitation. According to the author the lack of action between silver nitrate and carbon tetrachloride is not ascribed to the fact that the latter compound is a non-electrolyte, "for similar changes," he said, "do occur in the best of insulators" [10].

The history of electrolysis occupied considerable space in this text. First, as usual, came Faraday's contributions. A lengthy explanation of the electrolytic theories of Grotthus and Clausius preceded the statement of Arrhenius' theory. According to the author, the theory of Clausius can be distinguished from that of Arrhenius by the fact that the former held that the free, or undecomposed parts of an electrolyte would at any moment not amount to more than a

small fraction of one percent, while Arrhenius assumed the presence of a much larger percentage of dissociation. Kahlenberg said that this theory "is founded upon a supposed connection between the vapor tensions, boiling points, or freezing points of dilute solutions of electrolytes, on the one hand, and their electrolytic conductivity on the other hand" [10]. In setting forth the "assumptions" of Arrhenius' theory, the author pointed out that Arrhenius used the word "ion" in a different sense from that proposed by Faraday, "who regarded the ions as the substances that migrate toward the electrodes during actual electrolysis, not as part molecules charged with electricity which are at all times present in an electrolyte" [10].

Kahlenberg stated that the adherents of the Arrhenius theory hold that ions bear the same colors as do their aqueous solutions of their salts and that the acid properties of electrolytes of acids are due to hydrogen ions and the alkalinity of caustic alkali solutions to hydroxyl ions. "Indeed, in terms of the theory of electrolytic dissociation an acid would be defined as a substance capable of yielding hydrogen ions, while a base would be a substance capable of yielding hydroxyl ions" [10]. The author gave examples of instant precipitation in the "best of insulators" and pointed out that "lead will precipitate copper from insulating copper oleate solutions just as zinc precipitates copper from aqueous copper sulphate solutions" [10]. Kahlenberg stated several times that all the physical and chemical properties exhibited by salt solutions that are electrolytes can be duplicated in salt solutions that are insulators, except the phenomena of electrolysis. "The distinguishing feature of Arrhenius' theory is the claim that there is a quantitative relation between lowering of the freezing point or elevation of the boiling point and the electrical conductivity of solutions," but, according to the author, "the numerous cases thus far adduced to support this claim are not at all conclusive for they show variations that are far beyond the limits of experimental errors" [10]. For further argument he stated that the behavior of electrolytes in general is not in harmony with the law of mass action, "as ought to be the case if Arrhenius' theory were tenable" [10].

William A. Noyes, in a text published in 1914, gave three factors in support of the theory, one of which had not been noted before, that of an experiment by Tolman performed by centrifugation of sodium iodide. The Noyes text did not offer a systematic discussion of the theory. The above factor was given under a chapter entitled "Chlorine." In a later chapter as a sort of postscript he gave an explanation of the source of the charge on the ion, which was similar to that given by Remsen and as is set forth above. In a chapter entitled "Metallic Compounds," Noyes discussed effect of a common ion, solubility product, formation of complex ions, and degrees of ionization. This was the first book which devoted considerable space to an explanation of the formation of complex ions [21].

Two texts by Lyman C. Newell, published in 1914 and 1916, gave essentially the same treatment except that in the former the author was of the opinion that the theory of Arrhenius was adequate, and the revised edition indicated that the author thought the theory did not explain all the facts of solutions and that it would be modified to cover certain facts not within its scope. The general outline of the treatment of the theory was similar to that of the Remsen text. Newell's books were among the first to write ionic equations with the charges attached to the ions as we find them in modern texts [18], [19].

The second text of Kahlenberg, published in 1918, indicates that the author was of the same opinion concerning the theory as was shown by the earlier edition. He again based the weight of his arguments

on instant precipitation of solutions of good insulators, the corresponding colors of solutions of electrolytes and non-electrolytes, reasoning that the colors exhibited cannot be due to the ions present, the heats of neutralizations of some of the weaker acids being the same as some of the stronger acids, although the latter are supposedly far more highly dissociated, and again concluded that the physical and chemical properties exhibited by salt solutions that are electrolytes can be duplicated in salt solutions that are insulators, except for the phenomena of electrolysis themselves. According to Kahlenberg, "the electron theory has thus far not proved to be of special value in chemistry" [11]. This text and the author's 1910 edition were the only books examined thus far which mentioned ionizing solvents other than water. They were liquid ammonia, amines, liquid hydrocyanic acid, alcohols, esters, ketones, and sulfur dioxide [11].

Alexander Smith's 1922 edition devoted thirty-seven pages to an explanation of and experimental data to support the theory. His was the first book examined which devoted more than one complete chapter to its treatment. Under a chapter entitled "Ionization" he explained electrolysis, discussed the nature of ions, ionic equilibrium, the conductivity phenomena as a means of measuring the fraction ionized, and the relation between the extent of ionization and chemical activity. This was the first text to explain primary and secondary products formed in electrolysis. The author gave considerable space to answering what he considered perplexing questions which might arise from a study of the theory. One of them was the same that was asked by Cleve, Arrhenius' professor at Upsala, i.e., "In a solution of sodium chloride, if there is a sodium ion present why does it not exhibit any of the properties of the metallic sodium, and if there is chlorine present, where is the greenish gas?" Smith explained that the sodium and chlorine atoms are not set free, but that the ions are, and that their properties are entirely different from those of an atom of the element. Under the second chapter devoted to the theory, entitled "Ionic Substances and Their Interactions," the author enumerated the various classes of "ionogens," acids, bases, and salts. He then cited examples of three ways in which ionic equilibria can be displaced. As was customary for texts of this period, included in the same chapter was a discussion of neutralization, acidimetry, and alkalimetry. A third chapter entitled "Dissociation in Solution" was devoted to illustrations of "proofs" that the molecules of acids, bases, and salts in aqueous solutions are actually dissociated into parts by the solvent. Again there was no mention of Arrhenius in connection with the theory, and there was no suggestion that the existing theory was not adequate for strong electrolytes [27].

An interesting suggestion as to why the results obtained for measurement of conductivity of strong electrolytes do not conform to Arrhenius' theory was given in Deming's text of 1923. He said, "Perhaps the simple dissociation of molecules into ions, uncomplicated by other phenomena, will be found in the end to occur only in very dilute solutions" [3]. Deming gave a concise statement of the theory with the notation that it was postulated by Arrhenius in 1887. The source of the charge on the ions was explained in terms of loss and gain of electrons when the electrolytes are placed in a solvent; and Deming mentioned ionizing solvents other than water as liquid ammonia, liquid SO_2, and liquid HCN. To support the theory the author gave two methods of determining the degree of ionization, measurement of freezing point lowering, and conductivity. He pointed out that the results for concentrated solutions are irregular for reasons not understood, and he gave the above quotation as to why [3].

Holmes' treatment of the theory in a text of 1924 was similar in general outline to Smith's 1922 edition. His definition of an ion was different from the usual one. "A sodium atom carrying a positive charge of

electricity is called an ion and is soluble in water, invisible, and does not react with water" [6]. Considerable space was given to asking and answering questions concerning the source of the charge on the particles, interionic attraction, and why ions of substances do not exhibit the same properties as atoms of the same substances. A chapter entitled "Applications of the Ionic Theory" gave discussions of conductivity and ionization, the properties of electrolytes, "ionogen" reactions, neutralization, and hydrolysis. Holmes did not emphasize the fact that solutions of strong electrolytes do not conform to the theory [6].

The Debye-Huckel theory made its first appearance in the texts examined in that of H. I. Schlesinger, published in 1925. Up to this time, only a few of the books had given any clue that certain inconsistencies exist between the Arrhenius theory and facts known on such subjects as atomic structure, crystal structure, and even the source of ionic charge. Schlesinger opened his discussion of ionization by attempting to clear up just what is meant by "extent of ionization." He considered the term to be a correct and definite one if it refers to the fraction of molecules in which the complete severance of an electron from one atom and its complete capture by another when the substance is dissolved in a solvent. For the purposes of his book, he assumed 100 percent ionization, but stated that "the correctness of this assumption is somewhat doubtful, at least in very many instances, but in qualitative discussions of the behavior of ionized solutions no important error will result from it" [25]. The author discussed the degree of ionization of weak electrolytes and said that the methods of determining the degree of ionization of the weaker electrolytes still holds as Arrhenius first set it forth. He offered two probable explanations of why the positively and negatively charged particles, which attract and repel each other ordinarily, do not get together to form molecules. First, the solvent prevents this, because all solvents in which ionization occurs are liquids of high dielectric constant. Second, he said there is a possibility that the solvent forms a rather unstable compound with the ions and this compound formation may prevent the passing back from the negative ion to the positive ion of any electron. He mentioned ionizing solvents other than water as sulfuric acid, formic acid, liquid ammonia, alcohols, and fused salts. Besides these, there were no other noticeably different features of the author's treatment [25].

James Kendall's *Smith's Inorganic Chemistry* will be used as an illustration of the treatment the theory received after the DeBye-Huckel theory began to make its appearance in the texts. This edition was published in 1926. Among Kendall's opening remarks in his first chapter on ionization was "results of recent researches have shown that the theory as originally developed is in need of drastic modification" [13]. A lengthy statement of Arrhenius' theory was followed by the usual definitions of cations, anions, electrodes, etc., along with a discussion of the migration of ions with the pointed explanation that the charges are neutralized upon reaching an electrode and the resulting atom of the element is discharged and not the ion. The experimental basis of Faraday's law of "equal quantities of electricity discharge equivalent quantities of ions" was demonstrated, and was followed by a definition of polarization. In further support of the theory, Kendall illustrated how acids divide in electrolysis so as always to liberate hydrogen. Also listed was the experiment devised by A. A. Noyes, using the U-tubes to show ionic migration. Under a discussion of the conductivity of ions the author listed three conditions on which the actual conductance of any solution will depend, the number of ions between the electrodes, the number of charges upon each ion, and the rate at which the ions move [13].

In distinguishing between Arrhenius' and the modern theory, Kendall pointed out that Arrhenius assumed that as the concentration of an electrolyte in a solution is varied, its extent of ionization changes

while the mobilities of the ions remain constant, but that for most electrolytes, the quantitative changes in the degree of ionization with concentration are not at all in agreement with the law of molecular concentration. He said that the modern theory postulated that the rate at which the ions move is not independent of concentration, but is a function of the environment in which the ions exist. Kendall carefully pointed out, however, that this suggestion may be carried to the extreme by considering the possibility that the extent of ionization remains constant when the concentration is changed, and that the ionic mobilities alone vary. It was under a discussion of ionic equilibrium that Kendall gave perhaps the strongest support of the modern theory. He pointed out that Arrhenius assumed that the proportion of molecules ionized is found by conductivity measurements to become greater as more and more of the solvent is added and that the removal of the solvent diminishes the proportion of ions to molecules, and finally leaves the substance entirely restored to the molecular condition. Thus, ionization would be a reversible reaction and therefore a true dissociation. Again he recalled that for strong electrolytes the equilibrium constant does not remain constant, but changes with the concentration of the solution used. Next followed an explanation of the activity concept, although Kendall did not refer to it as such. He then illustrated how the Arrhenius theory is completely in accord with the experimental facts for the ionic activity of weak electrolytes [13].

In a second chapter entitled *Ionic Equilibrium,* Kendall gave the three methods of displacing ionic equilibrium which Smith enumerated in his 1922 edition. He gave two instances in which extensive chemical change ensues when two highly ionized substances are mixed and gave examples of each. This was followed by an up-to-date explanation of the role of the solvent in ionization, and as a conclusion to this chapter Kendall again proposed to clarify what Smith had considered some confusing problems such as the source of the charge on the ion and why ions of substances do not exhibit the same properties as atoms of substances. There was no mention of Debye and Huckel in connection with the modern theory. Kendall devoted some sixty pages to the treatment of the theory [13].

Compared with Kahlenberg's statements on the colors of solutions of certain electrolytes, Holmes' assertions in his *Introductory College Chemistry,* published in 1931, are considerably different. "Copper ions must be blue since dilute solutions of copper sulfate are blue. It may be objected that the blue color is due to molecules. This cannot be true, however, because the dry salt heated until all water is lost, is white, yet only molecules remain" [17]. Holmes devoted thirty-two pages to the theory, and his treatment was essentially the same as the Kendall text of this period.

A text by John Arrend Timm, published in 1932, showed a slightly different treatment. Before taking up the theory, the author gave a ten page discussion of solutions in general, their electrical properties, vapor pressures, freezing and boiling points, and how molecular weight is determined therefrom, mol fraction, and molecular concentration, osmotic pressure and its measurement. The chapter on electrolytic dissociation introduced the theory by setting forth the facts that were known to Arrhenius about solutions, which was followed with a summary of Arrhenius' theory and an explanation of why his theory had to be modified. Timm based this need for modification on the idea that a polar linkage exists in the solid electrolyte and that in weak electrolytes there is an intermediate type of linkage between the polar type and the non-polar and that a "partial transfer of an electron may occur in these intermediate types which are found in the molecules of weak electrolytes" [31]. He explained the activity concept, but did not refer to it as such. The author pointed out that some strong electrolytes are completely ionized in the crystal or solid state, and that these particles are charged "atoms

rather than molecules," and for this reason he believes that strong electrolytes are completely ionized in aqueous solutions [31].

Horace G. Deming's text of 1933 made several additions not found in texts before. The author opened his discussion with the role of the solvent, pointing out that water is not the only solvent that furnishes conducting solutions. He then discussed diluting solutions of active and slightly active acids, bases and salts, noting that diluting solutions of active acids, bases, or salts has little effect on the total conductivity because they are completely ionized already. Deming explained clearly and simply the activity concept when he dealt with methods of determining the degree of ionization. This was the first text examined which gave considerable space to a discussion of atomic structure in connection with ionization. Deming showed the grouping of electrons and how ions are formed. There was nothing outstandingly different in the author's treatment other than that which has been noted above. There was a suggestion, however that the author was not in complete accord with the theory of 100 percent ionization [4].

Two revisions of James Kendall's *Smith's College Chemistry,* appearing in 1935 and 1936, were found to be essentially the same in the treatment of the theory. Under his discussion of the modern theory the author made several new additions in both texts. He pointed out that Professor A. A. Noyes, as long ago as 1908, referred to the possibility that the so-called undissociated fraction of a salt in solution, say NaCl, might exist in a potentially ionized condition, the atoms being oppositely charged but held together by their mutual attraction [12], [14]. The 1935 edition was the first text examined which mentioned the work of the Braggs on crystal structure, and Kendall pointed out that the extension of their ideas to solutions was delayed until the theory of complete ionization was put forward by Debye and Huckel [14].

B. Smith Hopkins' *General Chemistry for Colleges,* appearing in 1937, was the second to give Professor Richard C. Tolman's experiment in support of the theory. There were no other outstanding differences in the Hopkins text. It was similar in general outline to other texts of this period [8].

This study terminated with textbooks published through 1940, but the several other books appearing after 1937 failed to show any noticeable differences in treatment. By 1936 the treatment of the theory did not differ greatly from that we find in our up-to-date textbooks. Both Arrhenius' and the modern theory were given in great detail, and such terms as "drag effect," "dipole moment of solvent" and "activity concept" were frequently used in explanations of the modern theory. The limitations of Arrhenius' theory were emphasized, yet the theory was deprived of none of its value when applied to weak electrolytes. Some of the authors indicated that they were not in complete accord with the Debye-Huckel theory of complete ionization, but they appeared to be of the opinion that any explanation of the inactivity, or apparent inactivity, of certain percent of the ions of strong electrolytes would serve equally as well.

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A COURSE IN PHYSICAL SCIENCE

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The course, which is called "Introduction to Physical Science," may be described as a study of some of the important principles and generalizations in the physical sciences, along with some of the data or "facts" which support these principles. Topics are selected without regard to the fields into which physical science has been formally divided. However, in terms of the conventional divisions, materials from physics, astronomy, chemistry, and the earth sciences (including meterology) are included. In some cases, for illustrative purposes, the techniques of scientific investigation are described in detail. Wherever appropriate, the broader aspects of the "scientific method," including the significance of scientific laws and hypotheses, are considered in conjunction with the study of specific topics. Although primarily a course in science, the interrelations of science and technology with our present-day culture are included, not as separate topics to be discussed and dismissed, but rather as part of the study of various subjects within the course. This includes philosophic as well as social and economic factors.

The course is given as a six hour, two

* The author wishes to acknowledge the contribution of Dr. R. R. Edwards in suggesting that a theoretical history of the universe be used as the basic outline for a course in physical science.

semester course, with two classes and one laboratory-discussion session each week. This is not to imply that the classes are formal lectures in contrast to the discussions. Since the enrollment of the class is limited to 25 or 30 students, the classes are conducted with a maximum of student participation consistent with suitable progress. A textbook is used as a core for the student's study, but other readings are frequently assigned. The textbook used is *The Study of the Physical World* by Cheronis, Parsons and Ronneberg (Houghton Mifflin Company).

The laboratory-discussion sessions are predominantly for student activity and whenever feasible experiments are chosen which the students can perform. For astronomy there is an outdoor session in the evening, with a telescope. Geological field trips and industrial tours are also part of the laboratory work. Movies are frequently shown in connection with demonstrations, and in the case of the latter, students are often asked to read an instrument and report the results to the class. In a few cases the laboratory time is used for supervised problem solving and discussion of textbook material or previous laboratory results. Most of the quizzes and examinations are given during the laboratory-discussion periods.

An attempt is made in the examinations to encourage the student to do three things: To acquire and retain a certain minimum amount of factual information, to develop some ability to use this information in the solving of problems, and to realize the significance of some of the ideas of science in framing a mental picture of the world around us. To this end the examinations include three general kinds of questions. (1) A considerable number of simple, short-answer questions of a purely objective type are given, including some that depend merely on memory and some that involve a certain amount of thinking on the part of the student. (2) A few problems, some of which may be of a numerical nature, are given. (3) Discussion questions are given which may be over a relatively narrow field and which may be framed to give the student a certain amount of guidance, or the topic may be very broad with no particular limits except those which the student makes for himself. (Often, when the latter type of question is given the following statement is inserted parenthetically: "You will be graded on organization, completeness, and accuracy.")

The framework around which the material of the course is organized is a theoretical history of the physical universe. Various theories are mentioned, but the outline is based upon a theory of the development of the present universe from what appears to be one of the simplest forms of matter, the neutron. The changes in this matter are traced from a homogeneous, primordial fluid through the formation of atoms and molecules to the development of galaxies, stars and planets. Then the appearance of rocks and minerals on the earth, and their interaction with the atmosphere and hydrosphere are considered. With the emergence of life, "organic" materials come into the picture. Finally the creative works of man in the physical sciences are reviewed in regard to two main aspects. First: The practical applications of science as exemplified by the synthesis of new materials and the development of modern communications and power. Second: The manner in which man has explored and exploited these physical phenomena to the extent that theories such as we have studied may be developed and given credence. It should be noted that the course is not concerned with creation but rather with some of the processes by which the present universe may have developed from material already in existence.

The following topical outline indicates more specifically how the material of the course is presented. It is obvious from this outline that if all of the topics were developed rigorously and in detail, there would be far more material than is suitable

for a general course. Some subjects are treated more thoroughly than others, with the teacher making the choice in emphasis, based in part on student interest.

I. The Background for Physical Science.
  A. The Assumption of a real and objective external world.
  For the purposes of this course this assumption is made without going into the philosophic background and implications. The existence of other lines of approach is recognized.
  B. The relation of observables to the senses.
    1. The relative objectivity of observations.
    For example, contrast the designation of color, the feeling of hot or cold and the simple process of counting a series of items.
    2. The importance of quantitative measurement.
    This is the basis for the statement that "Mathematics is the language of science."
    3. Observations may be direct or highly indirect.
    Contrast the simple observation of the existence of the moon with the complicated determination of the size of a star which is not even visible to the naked eye.
  C. The subject matter of the physical sciences.
    1. The scope of physical science.
    The physical sciences are concerned with the study of matter and energy and their interactions. (The object of this course is to amplify the meanings of the terms "matter" and "energy," and to learn the nature and significance of some of their interactions.)
    2. Examples of phenomena of interest.
      a. What causes the seasons?
      b. What are the possibilities of life on other planets?
      c. How does a lighting circuit work?
      d. Are there many materials that could be used for an atomic bomb?
      e. Are there "universes" other than our own?
      f. Why do some regions have so much more rainfall than others?
      g. What is a seismograph and how does it work?
      h. What is the Milky Way?
      i. What is the relation between radio, television, and radar?
      j. What were the ice ages?
      k. What are comets and falling stars?
      (These are merely examples of possible questions that might be included at this point. Each student is asked to make up a similar list to include topics of special, individual interest. The instructor then chooses those topics most suitable for inclusion in the course and augments the list if desirable.)
  D. The place of theories in science.
  (No extensive discussion of the scientific method is indicated here, but rather a simple introduction to furnish a background for taking up one of the theories of cosmogony.)

II. A Primitive Universe.
  A. The "primordial fluid" and its properties.
    1. Extent: Length, area, volume—the concept of space.
      a. The necessity of units for a quantitative approach. Note the contrast between primitive units, the English system and the metric system.
      b. The mathematical operations involved in expressing area and volume.
    2. Mass.
    There are two characteristics by which we become aware of mass and measure it.
      a. Inertia.
      b. Gravitational attraction.
        (1) The inverse square law.
        (2) The relation of mass to weight.
    3. Density: the mass-volume ratio.
    This involves the ratio of units and the mathematical operation of division. (The densities which some postulate for the primordial fluid are extremely high.)
    4. Discontinuity or infinite divisibility? (Democritus vs. Aristotle) It is assumed that the *neutron* is the ultimate (and only) particle present in the primordial fluid at the beginning.
  B. Expansion of the fluid and some related changes.
    1. The movement of particles in a fluid.
      a. The concept of kinetic energy.
      b. The relation of temperature to the energy of particles.
      (The temperatures postulated for the primordial fluid are very high.)
    2. Radiation as a form of energy.
    (A high density of radiation is assumed at the beginning of the expansion of the fluid.)
    3. The conversion of kinetic energy and radiation into potential energy.
      a. Relation of expansion to cooling.
      b. The law of conservation of energy.
    4. The concept of entropy as related to order and disorder in the fluid.
  C. The appearance of protons and electrons.
    1. The decay of neutrons.
      a. The spontaneity of the process.
      b. The half-life period.

2. The concept of electric charge.
   a. The existence of positive and negative charges.
   b. The attraction and repulsion of electric charges.
      The inverse square law as applied to charges is compared to the same law in connection with gravitational attraction.
3. Energy relationships.
   a. The loss in mass and its conversion into energy.
   b. Einstein's equation for the mass energy relationship as an extension of the law of conservation of energy.
4. The importance of these three particles (neutrons, protons and electrons) as "building blocks" of matter.

III. The Formation of More Complex Particles, and Some of Their Properties.

A. The formation of nuclei.
   As the mixture of protons, electrons and unchanged neutrons expands and cools these particles interact with each other as well as with the larger particles being formed.
   1. Neutron capture and related reactions.
      a. Deuteron formation.
         There is a loss in mass with consequent emission of energy (an exoergic process). The binding energy is a measure of stability.
      b. The formation of tritons and their disintegration to tralpha particles.
         This neutron capture and intranuclear decay of neutrons could continue to give many different complex nuclei. (Plutonium for the atomic bomb is now produced by such reactions from uranium.)
   2. Other nuclear reactions of interest.
      a. The indirect formation of a helium nuclei from four protons (as in the sun).
      b. The formation of a helium nucleus (alpha particle) from a triton and a deuteron (the probable reaction in the hydrogen bomb).
      c. The loss of an alpha particle (as in the case of radium and other complex, unstable nuclei).
      d. Nuclear fission.
         This is the process taking place in the "atomic" bombs.
      e. Gamma radiation from unstable nuclei.
   3. Some generalities concerning nuclides.
      a. Always positively charged, due to protons.
         Nuclei with charges of from 1 to 100 are known (atomic numbers).
      b. All contain neutrons (except ordinary hydrogen nuclei).
      c. Number of neutrons equal to or greater than number of protons (with two exceptions).
      d. Exceptional stability of the alpha particle.
      e. Mass of nuclides always less than the sum of masses of constituent particle.
         This difference in mass varies and this variation makes possible the atomic bomb.

B. The combination of nuclei with electrons to form atoms.
   As further expansion and cooling take place the temperature becomes low enough to permit atoms to form and remain stable.
   1. The neutrality of atoms due to balance of electrons and protons.
      This neutrality gives added stability to the system.
   2. The periodic arrangement of electrons around the nucleus.
      Two important phenomena are affected by the periodicity.
      a. The absorption and emission of electromagnetic radiation.
         (1) The wave nature of this radiation.
         (2) The quantization of the energy of this radiation.
             The particle nature of energy is comparable to the atomicity of matter.
      b. The interaction of atoms with each other.
         These atoms are the unit particles of the chemical elements and their interactions constitute their chemical properties.

IV. Intercombinations of the atoms to form more complex substances (chemical reactions).

A. The electrical nature of the union between atoms.
   1. The dependence upon the electrons in the atoms involved.
      The position of the outer electrons determines the number that take part and the manner in which they react.
   2. The two principal ways in which the electrons take part.
      a. The gain and loss of electrons to form charged particles called *ions*.
      b. The sharing of electron pairs between atoms to form molecules.

B. Energy relationships.
   1. The relation of stability to energy content: *exothermic* and *endothermic* reactions.
   2. The law of conservation of energy.

C. The law of conservation of matter.
   This is probably only an approximation.

D. The concept of equilibrium.
   1. The dynamic aspect of chemical equilibrium.
   2. The principle of Le Chatelier.
      This is a very broad principle which appears to apply in many different fields and beyond the physical sciences.

E. The molecule as a unit of matter.
   1. Chemical reactions between molecules;—examples.
      Distinguish between an atom and a molecule.
   2. The kinetic molecular theory.
      a. Molecular motion as a form of energy.
      b. The behavior of gases,—pressure, temperature, volume relationships.

V. Changes in the distribution of matter in space.
   A. Gravitational attraction and the expansion tendency as opposing forces.
      Due to the motion of the particles there is a tendency to expand. At the same time the random motion is decreased (the matter cools) and this increases the chance for the gravitational attraction to bring the particles together in small groups.
   B. Aggregation of the compounds and elements to form galaxies.
      1. The conditions that would contribute to the growth of galaxies.
         a. The various forms of galaxies.
         b. The Milky Way.
      2. The composition of the galaxies, and the distribution of matter within them.
      3. The number and distribution of the galaxies, and the relation of our galaxy to the others.
   C. Stars as astronomical units.
      1. The various types of stars.
      2. A brief life history of a main sequence star.
         a. Possible modes of formation of stars within a galaxy.
         b. The growth of stars, changes in size, temperature, etc.
         c. The decay of stars and their probable fate.
      3. Nuclear processes as the primary source of stellar energy.
         (Consider the relations of mass and pressure to the temperatures necessary for thermonuclear reactions.)
      4. Our sun as a typical star.
         a. The sun's position in the galaxy.
         b. Size and temperature.
         c. Composition of the sun.
         d. The sun as a source of energy.
            (1) The conversion of hydrogen to helium and the resulting changes in composition and mass.
            (2) The nature of the energy radiated from the sun.
   D. The planetary systems.
      1. Theories of the formation of planets.
         Many theories have been proposed, but none are satisfactory in all respects. (Two or three of the more prominent hypotheses are very briefly considered.)
      2. The ubiquity of planetary systems.
         This is a matter for speculation and one's conclusion must be based primarily on the theory of formation. The philosophical consequences are rather far-reaching.
      3. The members of the solar system.
         a. The number and relative positions of the planets and planetoids.
         b. The satellites of the planets.
         c. The comets and meteors.
      4. The nature of the planetary orbits, laws of motion, etc.
         (A brief historical review is included here to illustrate the rise and fall of theories and the relation of such theories to ancient and medieval thought.)
         a. The Ptolemaic or geocentric system.
         b. The Copernican or heliocentric system.
         c. Kepler's laws applied to the heliocentric system.
      5. Important aspects of the earth's relation to the solar system.
         a. The rotation of the earth.
            (1) The equator and the poles (both terrestial and celestial); Longitude and latitude.
            (2) The apparent diurnal motion of the sun, moon and stars on the celestial sphere.
         b. The revolution of the earth about the sun and the inclination of the earth's axis.
            (1) The distribution of climate on the earth.
            (2) The seasons.
         c. The revolution of the moon about the earth.
            (1) Phases of the moon.
            (2) Eclipses of the sun and moon.
         d. The measurement of time: Year, month, day, etc.

VII. The earth: Its present features and their development.
   A. General description.
      1. Size and shape.
      2. General structure of the earth.
      3. Composition of the earth.
         a. The crust.
         b. The interior.
         c. Comparison with cosmic abundances.
      4. The earth's magnetic field.

B. The lithosphere and some geologic processes affecting its nature.
   1. Diastrophism.
      a. Possible causes of earth movements.
      b. Formation of continents, mountain building, etc.
   2. Vulcanism and the formation of igneous rocks.
      a. Sources and types of magma.
      b. Results of vulcanic activity (volcanic cones, intrusions, dikes, etc.).
      c. Important ores that vulcanism has produced (gold, copper, etc.).
   3. Metamorphism.

C. The atmosphere and hydrosphere and their relationships to the lithosphere.
   1. Possible methods of formation from the primeval lithosphere and the resulting chemical composition.
   2. Gradational processes.
      a. Relation of weathering to degradation.
         (1) Processes involved (chemical and physical).
         (2) Ores produced by weathering (iron and aluminum).
      b. The transporting agents in degradation.
         (1) Water, stream erosion.
         (2) Ice, glaciation; the ice ages.
         (3) Air, ancient and modern dust bowls.
      c. Aggradation.
         (1) Sedimentation processes.
         (2) The formation of sedimentary rocks, and their metamorphosis.
      d. Gradation as opposed to diastrophism and vulcanism.
      e. Soil conservation as related to gradation.
   3. Variations in the oceans, lakes, and rivers during the earth's history.

D. The age of the earth and its relation to the cosmic time scale.
   Consider some of the methods of measurement, the results obtained and the uncertainties involved in this type of estimate.
   1. Radioactivity studies.
   2. Rates of sedimentation.
   3. Salt content of the oceans.

E. The interrelationships of weather and climate to the topographical features of the earth.
   1. The effects of the atmosphere on insolation and the energy balance at the earth's surface.
   2. The relation of the movement of the atmosphere to variations in pressure.
      a. Effects of uneven heating of the earth's surface, including large bodies of water.
      b. Effects of variations in altitude of the surface.
      c. Effects of the rotation of the earth.
   3. The transport of water by the atmosphere.
      a. Evaporation and relative humidity.
      b. Cloud formation.
      c. Precipitation.
         (1) Types (Snow, hail, dew, rain, etc.).
         (2) Conditions conducive to precipitation (including artificial seeding of clouds).
   4. Air mass analysis and weather forecasting.
   5. Special phenomena of interest, including hurricanes, tornadoes, and their relations to cyclones.

VIII. Further complex chemical changes on the earth—substances related to life processes.

A. Some relatively simple compounds of carbon.
   1. The hydrocarbons.
   2. Compounds containing carbon, hydrogen and other elements.
      a. Oxygen compounds: Alcohols, ethers, aldehydes, acids.
      b. Nitrogen compounds: Amines, amides and amino acids.
      c. Sulfur and phosphorus compounds (mention only).

B. The chemical nature of the main types of foods.
   1. Carbohydrates.
      a. Simple and complex sugars.
      b. Starches and cellulose,
   2. Fats and oils.
   3. Proteins and their relation to the amino acids.

C. Other carbon compounds essential to living organisms.
   1. Vitamins.
   2. Hormones.
   3. Enzymes.

D. Energy relationships in photosynthesis and metabolism.

E. The formation of carbonaceous minerals: Coal, petroleum, and natural gas.

IX. Some simple machines.

Man has found it helpful to increase the speed or force of his muscular action by the use of certain mechanical devices.
Note the output-input ratios of forces or velocities.

A. The wheel—a means of decreasing friction.

B. The lever type of machine.
   1. The simple lever. Applications.
   2. The "rotating lever" as in the wheel and axle of a windlass, or in gears.

C. The inclined plane type.
   1. The simple inclined plane.
   2. The wedge.
   3. The screw.

D. The pulley and combinations of pulleys.

X. The production and transmission of energy for man's machines.
- A. The primary sources of energy.
  - 1. Radiant energy from the sun.
  - 2. Nuclear energy from terrestrial sources.
  - 3. Energy derived from the motions of earth and moon. This includes the tides and to some degree the wind.
- B. Immediate sources of energy of greatest importance.
  - 1. The use of combustible materials.
    - a. Wood and similar materials.
    - b. The fossil fuels, i.e., the carbonaceous minerals.
  - 2. Water power.
  - 3. The wind.
  - 4. Atomic energy (more correctly called *nuclear* energy).
    - a. The relative availability of fissionable materials.
    - b. The future usability of this source.
- C. The transmission of energy.
  - 1. Radiant energy. This is not generally transmitted as such to be used to operate machines. (Some exceptions may be noted.)
  - 2. Mechanical energy. This usually involves belts, gears, and shafts and is generally used for short distances only.
  - 3. Chemical energy. This is transferred only insofar as the materials which have the chemical energy are transported.
  - 4. Heat energy.
    - a. By conduction. This is important for very short distances only.
    - b. By convection.
      - (1) Space heating (hot air, hot water, steam).
      - (2) Cooling devices (automobile radiator, etc.)
  - 5. Electrical energy. This is very common and is used for transmission over relatively long distances.
    - a. Electrical conduction and the electric circuit.
    - b. Relations between voltage, current, and resistance.
    - c. Efficiency of transmission and voltage—the importance of the transformer for alternating current.
- D. Devices for the conversion of energy: Applications of the law of conservation of energy.
  - 1. Electric generators and electric motors. Some of the simpler relations between moving conductors, electric currents, and magnetic fields.
  - 2. Batteries and the electrochemical cell.
    - a. The general nature of the chemical changes taking place.
    - b. Some different types of batteries.
    - c. Some applications of electrolysis.
  - 3. Heat engines and heat pumps.
    - a. The relation of efficiency to temperature.
    - b. Refrigeration and reverse refrigeration.
    - c. The perpetual motion machine—its impossibility.
- E. Energy and the industrial revolution.
  - 1. The change from animal power to other sources.
  - 2. The increase in energy requirements per capita.
  - 3. The increase in different uses of energy.
    - a. Heating, i.e., space heating for dwellings, working quarters, etc.
    - b. Mechanical work—transportation, generation of electricity, fabrication.
    - c. To produce chemical transformations. (See the next section.)

XI. Man's production and use of new materials. The chemical industries are concerned with the preparation and properties of some of the useful substances that do not occur naturally or occur in insufficient amounts for man's purposes.
- A. Metallurgy.
  - 1. The ores as sources of metals.
    - a. The geological background—types of ores and locations.
    - b. The economic aspects—the term ore as an economic concept.
  - 2. The Iron Age—old and new.
    - a. How iron is obtained from the ore.
    - b. The versatility of iron as exemplified by cast iron, steels of many kinds, alloys, etc.
    - c. The economic importance of iron and its relation to other industries.
      - (1) Fuels—the iron industry is both a consumer and a contributor for the coal and fuel gas industries.
      - (2) Transportation—both iron and its by-products contribute here.
      - (3) Miscellaneous — chemical, domestic items, etc.
  - 3. Some other metals of importance—The possibilities of a coming "Age of Light Metals."
    - a. Aluminum.
      - (1) Sources—The limitations of present ores compared with the "inexhaustible" (but unused) amounts in clay.
      - (2) The production of *alumina* and of *aluminum*.
        - (a) Brief description of the processes.

(b) Economic importance to the state of Arkansas.
b. Magnesium.
(1) The ocean as a source of metals.
(2) Production and uses. Alloys.
4. A reviewing statement of the physical principles involved in metallurgy and the general types of processes.
a. Pyrometallurgy.
b. Hydrometallurgy.
c. Electrometallurgy.
B. Ceramics.
This involves primarily materials containing silica. Other oxides including those of aluminum, calcium, sodium, and iron are often present also.
1. Clay products: Brick and tile, porcelain and china.
2. Cements (Portland cement and concrete), mortar, and plaster, etc.
3. The various types of glass.
a. Ordinary window glass.
b. Optical glass.
c. Heat resistant glass: Pyrex, etc.
C. Some chemicals essential to industry.
1. Important products from common salt.
(Soda, chlorine, caustic soda, etc.)
2. Typical chemicals from sulfur. The importance of sulfuric acid.
3. Miscellaneous materials, including fertilizers.
D. New compounds of carbon—Synthetic organic chemistry.
1. High polymers.
a. "Plastics."
b. Synthetic rubber.
c. Textile fibers.
d. The silicones.
2. Other compounds of interest.
a. Dyes.
b. Explosives.
c. Insecticides, etc.
d. Drugs and antibiotics.
e. Detergents.

XII. Communication.
This section is concerned with the physical nature of various means of communication and some of the principles underlying their operation.
A. Sound.
1. Sound considered as longitudinal waves in solid, liquid, or gaseous media. The relation of frequency, wave length, and velocity.
2. The generation and detection of sound.
a. General methods.
b. Energy considerations.
3. Musical sounds—the physical basis of music.
a. The characteristics of a musical tone.
(1) Pitch.
(a) The relation of frequency to pitch.
(b) The musical scale.
(2) Loudness.
(3) Quality or timbre.
b. Types of musical instruments as sound producers.
4. Supersonic waves—their generation, detection, and uses.
B. The use of electric currents.
This involves interrupting or otherwise varying electrical currents in such a manner as to allow messages to be sent along electrical conductors.
1. The telegraph.
2. The telephone.
a. How sound produces impulses in the electric current.
b. The use of the electromagnet in the receiver.
C. Light.
1. The dual nature of electromagnetic radiation and the relation of energy to frequency.
2. A brief consideration of the principles of optics.
a. The reflection of light.
(1) Mirrors and the simple laws of reflection.
(2) Reflecting telescopes.
b. The variation of the velocity of light with the medium—refraction.
(1) The principle of the lens and its uses in microscopes and telescopes.
(2) Total reflection and its uses.
3. Color.
a. The visible spectrum—the relation of color to frequency and wave length.
b. The methods by which color may be produced.
(1) Dispersion, as by a prism.
(2) Selective emission by heated bodies.
(3) Partial absorption and reflection.
c. Hue, brilliance, saturation, and their relations.
D. The use of electromagnetic radiation beyond the range of the senses.
1. A comparison and contrast of light waves and radio waves.
2. The radio wave as a carrier.
a. Amplitude modulation.
b. Frequency modulation.
c. Phase modulation.
3. The transmitter—its dual function.
a. Generation of the waves.
b. Transferring sound or light signals to the carrier wave.
4. The receiver—its triple function.
a. Selection of the desired wavelength.
b. Amplifying the waves received.

c. Converting the modulations to sound or light.
5. The nature and use of radar and similar devices.
E. An over-all view of the various parts of the electromagnetic spectrum.
1. A comparison of the types of sources which produce the various frequencies.
2. A comparison of the effects and uses of the various frequencies.

XIII. In retrospect.
It is the purpose of this final section to present an over-all view of the methods and instruments of science which have been used in arriving at some of our present interpretations of the universe, based on the material presented in this course. To this end the following ramifications are suggested for consideration.
A. Alternative theories of cosmogony.
B. An analysis and evaluation of the scientific method, with special reference to its apparent limitations. (E.g. "Science Is a Sacred Cow.")
C. A consideration of possible future additions to man's knowledge, particularly with respect to sub-atomic phenomena and further exploration in distant space.
D. The validity or limitations of such fundamental concepts as entropy and the second law of thermodynamics, particularly with regard to life.
E. The place of man in the scheme of things as considered in this course.
F. The need for man to live in equilibrium with his physical environment. This necessitates conservation of natural resources in a complete sense. Eventually, inexhaustible supplies (such as solar energy, water, atmospheric nitrogen) must be used as widely as possible and limited materials (such as most of the metals) must be recovered and re-used.
G. The inadequacy of present knowledge.
This leads one to the realization that different interpretations of our universe are quite plausible. This is especially true at the present time with the limited knowledge now at hand. In the future, with much more additional knowledge, we may expect still other and different ideas about the nature of the universe.

JOE YOUNG WEST

It is with real sorrow that we announce the death of Joe Young West on April 29, 1955, as the result of a coronary thrombosis. The attack came as he was teaching his first class of the day at Towson State Teachers College. His students, his colleagues, and his friends were deeply shocked. Dr. West was born in Baird, Mississippi, January 4, 1904.

Joe West was always concerned about children. His work in the field of science education bears this out. Probably the first laboratory which might be described as a professional laboratory in elementary science was established by him at the State Teachers College at East Radford, Virginia. The fine features of his laboratory have been incorporated in professionalized laboratories in teacher-training centers in this and other countries.

While Joe was teaching in East Radford, he served as a science consultant in connection with the construction of the Virginia syllabus for elementary schools. This syllabus had great influence on the revision of curriculums in elementary schools throughout the United States.

Shortly after the completion of this syllabus, Joe began his doctoral study at Teachers College, Columbia University. His was a pioneer study in the field of evaluation, being concerned with a technique for analyzing children's observable behavior reactions. This study was the basis of a long series of studies of children's behavior in relation to science understandings. This approach to research has been so successful and has yielded so much information that from it has emerged a dynamic psychology of science education.

His concern for children led Joe into the field of writing books for their use. The outcome of this effort was the publication of several successful series of books with Scott, Foresman and Company. In addition, Joe contributed a number of articles on elementary science to this and other magazines. His contributions to science

education also included work in several professional organizations. Among these contributions was his service as president of the National Association for Research in Science Teaching from 1948 to 1949.

In the fall of 1937, Joe began his work in Maryland, at the State Teachers College in Towson and at the University of Maryland. His influence on the elementary science program through the work of teachers from these institutions has been great. A better education for children has been the result.

Both pre-service and in-service teachers who worked with Joe caught his enthusiasm about teaching children. Perhaps this was because Joe never allowed his interest in science to blind him to his concern for the fullest possible development of children. When he stated the purposes of science education, those purposes were child-centered rather than science-centered. When he worked with children, as he did constantly, he was alive to their questions, their misconceptions, their concerns, their challenges. Then he went about the business of helping them resolve their questions and concerns. He helped them meet the challenges. This, to Joe, was teaching in the fullest sense.

But Joe's story would be incomplete without some mention of his personal value to his friends, among whom were children, as well as adults. Joe's friends were numerous, for he gave of himself to each one. Social occasions were happier because of his warm friendship and delightful humor. No problem was too difficult for his cheerful, considered, and friendly appraisal.

Those who knew Joe West well, and these are many, will treasure the unusual warmth and generosity of his personality. Children and their teachers for years to come will benefit greatly from his inspired and inspiring work in the field of science education.

KATHERINE E. HILL

L. PAUL ELLIOTT

Regretfully we report the death of Dr. L. Paul Elliott from the result of a cerebral hemorrhage, December 25, 1954. He was born in Circleville, Kansas, February 23, 1901. Survivors include his wife Mary Myers Elliott, a son Larry Paul Elliott, a medical student at the University of Tennessee, Memphis, Tennessee, and a daughter Lee Anne Elliott, senior in high school in the P. K. Yonge School in Gainesville, Florida. He was a member of the Episcopal Church.

Dr. Elliott received B.S. (1923) and M.S. degrees from Kansas State College at Manhattan, and a Ph.D. degree from the University of Kansas. Teaching experience included Manhattan High School, Manhattan, Kansas; Ironwood Junior College, Ironwood, Michigan; Michigan State Normal College, Ypsilanti, and the University of Florida, Gainesville. He was Professor of Physical Science at the time of his death.

Membership in organizations include National Association for Research in Science Teaching, Phi Delta Kappa, American Association of Physics Teachers, American Association of University Professors, Lamba Chi Alpha and Kappa Phi Alpha. Before coming to Florida he served as President of the Michigan State Normal Faculty Club.

The writer does not have a list of his publications but we understand that his physics text will be released by The Macmillan Company this fall. He had been working also on another book, *The Theory and Practice of Teaching Science.* He served as science editor for Silver Burdett Company for many years.

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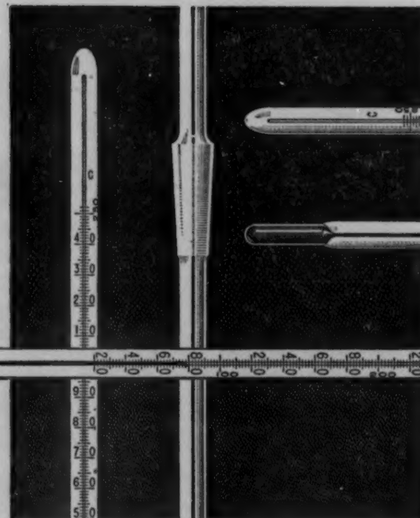

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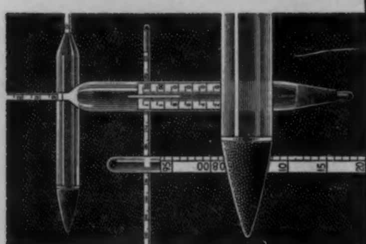

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